Limited health literacy, but not illiteracy, is associated with inadequate glycemic control in older adults with diabetes: a cross-sectional study

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Complete List of Authors:	Souza, Jonas; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine Apolinario, Daniel; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine Magaldi, Regina; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine Busse, Alexandre; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine Campora, Flavia; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine Jacob-Filho, ; Wilson; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine

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TITLE:

Limited health literacy, but not illiteracy, is associated with inadequate glycemic control in older adults with diabetes: a cross-sectional study

Jonas Gordilho Souza[a], MD; Daniel Apolinario[a*], MD, PhD; Regina Miksian Magaldi[a], MD; Alexandre Leopold Busse[a], MD, PhD; Flavia Campora[a], MD; Wilson Jacob-Filho[a], MD, PhD

[a] Geriatrics Division, Department of Internal Medicine, University of São Paulo Medical School, São Paulo, SP, Brazil

RUNNING TITLE:

Health Literacy and Glycemic Control

***CORRESPONDING AUTHOR AT:**

Geriatrics Division, University of São Paulo Medical School, Av. Dr. Enéas de Carvalho Aguiar, 155, 8º Andar, Bloco 8, São Paulo, SP, CEP 05403-900, Brazil. Tel.: +55-11-30696236

E-mail address: daniel.apolinario@usp.br

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ABSTRACT

OBJECTIVES: To investigate the relationship between health literacy and glycemic control in low-educated older patients with type 2 diabetes.

DESIGN: Cross-sectional study.

SETTING: A government-financed outpatient geriatric clinic in São Paulo, Brazil.

PARTICIPANTS: 129 older patients with type 2 diabetes, mean age of 75.9 (±6.2) years, mean HbA1c of 7.2% (±1.4), of which 14.7% had no formal education and 82.9% had less than a high-school diploma.

MEASURES: HbA1c was used as a measure of glycemic control. Health literacy was assessed with the Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA), a validated instrument to evaluate pronunciation and comprehension of commonly used medical terms. Regression models were controlled for extensive demographic data, depressive symptoms, diabetes duration, treatment regimen, diabetes knowledge, and assistance for taking medications.

RESULTS: Health literacy below adequate was encountered in 56.6% of the sample. Patients with inadequate health literacy were more likely than patients with adequate health literacy to present poor glycemic control. Adjusted OR for HbA1c ≥8 was 4.76 (95%IC 1.36-16.63) and adjusted OR for HbA1c ≥ 9% was 9.19 (95%IC 1.57-53.77). Illiterate individuals did not have poorer diabetes outcomes. In a multivariate linear model adjusted for confounding variables, higher levels of HbA1c were associated with lower health literacy levels, lack of assistance for taking medications, and longer diabetes duration.

CONCLUSION: Patients with inadequate literacy presented higher odds of poor glycemic control. Contrary to our expectations, illiterate patients did not have poorer outcomes, raising the hypothesis that these individuals are more likely to have their difficulties recognized and compensated. These findings reinforce the importance of identifying limited literacy in clinical practice.

ARTICLE SUMMARY

Article focus

• Although many theoretical mechanisms are proposed that link health literacy to diabetes self-care, the direct association between health literacy and glycemic control is still controversial.

• In particular, no studies have compared glycemic control between patients who have inadequate levels of literacy and those who are unable to read at all.

Key messages

• Older patients with inadequate health literacy were more likely to present poor glycemic control when compared to patients with adequate health literacy, but illiterate patients did not present a higher risk of poor glycemic control.

• Individuals who reported being unable to read at all are probably more likely to have their difficulties recognized and compensated. In contrast, among individuals who report being able to read, limited health literacy is a frequently unrecognized.

Strengths and limitations of this study

• A wide range of potentially confounding variables has been controlled, including depression, diabetes duration, treatment regimen, diabetes knowledge, and assistance for taking medications.

• The relatively small subsample of illiterate patients provided limited power to reject risk differences with small magnitude. Thus, these preliminary findings should be confirmed in further studies.

INTRODUCTION

Health literacy has been defined as "the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions".[1] The concept of health literacy is not restricted to the ability of reading medical prescriptions and calculating dosages. It includes a range of skills such as searching for specific health knowledge, evaluating information for credibility, analyzing risks and benefits, communicating needs, and negotiating preferences. Inadequate health literacy has been independently associated with poorer ability to take medications appropriately, lower utilization of preventive services, more hospitalizations, poorer overall health status, and higher mortality rates.[2]

Some segments of the population are at greater risk for inadequate health literacy, including the socioeconomically disadvantaged, immigrants, and older adults. In a study that included Medicare enrollees aged 65 years and older, health literacy skills declined dramatically with age, even after adjusting for educational status and cognitive impairment.[3] Inadequate health literacy may disproportionately affect the health of older persons, not only because it is more prevalent in this age group, but also because older persons are more exposed to health care services and more likely to receive complex therapeutic regimens.[4]

Diabetes care involves extensive self-management behaviors and requires pharmacological regimens that tend to become increasingly complex over time. It is a prototypical chronic disease which constitutes a representative model for studying the influence of health literacy on health outcomes. However, although many theoretical mechanisms are proposed that link health literacy to diabetes self-care and clinical outcomes, the direct association between health literacy and glycemic control is still controversial.[5]

In a recent systematic review, 13 studies were included that have explored the relationship between health literacy and glycemic control.[6] Results were inconsistent across studies, and the heterogeneity did not allow the estimation of an overall effect. Therefore, the evidence for direct association was rated insufficient. These findings may indicate that health literacy is related to certain outcomes in particular populations, but not in others. Only one study was conducted in a developing country, including a population with a very low levels educational attainment.[7] In that study, higher scores on the Short Test of Functional Health Literacy in Adults (S-TOFHLA) were strongly associated with reduced levels of glycosylated hemoglobin. In general, there is paucity of data at the very low end of the literacy status spectrum. In particular, no studies have compared glycemic control between patients who have rudimentary levels of literacy and those who are unable to read at all.

The purpose of this study was to determine the independent contribution of health literacy to glycemic control in a Brazilian population of heterogeneous, predominantly low-educated of older adults with type 2 diabetes.

METHODS

Subjects

A convenience sample was recruited between June 2011 and July 2012 from a government-financed outpatient geriatric clinic in the city of São Paulo, southeastern Brazil. During this period, 225 older adults with type 2 diabetes were screened for participation. At the time of the study, there was no diabetes management program or educational intervention in place. All patients were treated by geriatricians or geriatricians in training, were provided diabetes medications at no cost, and had access to the same range of services.

Research staff reviewed medical records and spoke with patients to verify inclusion and exclusion criteria. To be eligible, the subject had to meet the following criteria: (1) age ≥ 60 years; (2) speak fluent Portuguese; (3) type 2 diabetes currently being treated with daily medication; and (4) a glycosylated hemoglobin (HbA1c) measurement performed within a 6 month period. Patients were ineligible if they had a hearing, vision, motor or speech problem that precluded adequate interaction with the interviewer or impeded appropriate completion of the proposed assessments. Patients with a diagnosis of dementia were excluded because cognitive impairment has been associated with poor performance in health literacy tests and may affect an individual's ability to manage drug regimens.[8,9] Patients with overt thyroid dysfunction (thyroid-stimulating hormone < 0.1 or > 10mU/L), anemia (hemoglobin < 11 mg/dL for men and < 10 mg/dL for women), and severe renal failure (estimated glomerular filtration rate < 30ml/min/1.73m^2) were excluded because these conditions can affect the accuracy of the HbA1c assay.[10-12]

We further excluded subjects who fulfilled criteria for frailty, because less stringent targets of glycemic control have been proposed for frail elderly.[13] Frailty status was determined according to the Study of Osteoporotic Fracture (SOF) index.[14] The SOF index is composed of following three items: (1) weight loss of more than 5% during the last year; (2) inability to rise from a chair five consecutive times without using the arms; and (3) self-perceived reduced energy level evaluated by the question "do you feel full of energy?" Subjects were assessed systematically and excluded if at least two of the three criteria were fulfilled.

The research protocol was approved by the local ethics committee. Eligible patients attending to scheduled appointments were approached in the clinic waiting room and provided a description of the study procedures. An informed consent was obtained before the interview. The consent form was read aloud and explained in plain language for those individuals who declared to be illiterate or were judged by the interviewer as having questionable capacity to understand the form.

Demographic and Clinical Data

All participants were interviewed for demographic information, including age, gender, educational attainment (highest grade completed), race (white or non-white), and lifetime occupation (predominantly manual or non-manual). Individuals were further classified as married (including cohabiting) or unmarried (never married, divorced or widowed). Economic status was determined according to the Brazilian Economic Classification Criterion,[15] which provides a discrete scale calculated by assigning scores to the number of household assets.

Duration of diabetes was registered and treatment was characterized as oral agents alone or an insulin-containing regimen. Participants were further asked if they had supervision or help taking medications and classified as receiving assistance or not. Because some studies have reported depression as an important factor influencing glycemic control,[16] we assessed depressive symptoms using the 15-Item Geriatric Depression Scale (GDS-15).[17,18]

Health Literacy

We assessed health literacy by using the 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18), a test which evaluates pronunciation and comprehension of commonly used medical terms. The SAHLPA-18 has been previously validated in a sample of Brazilian older adults, presenting moderate to high correlations with construct criteria, high internal consistency, and adequate test-retest reliability.[19]

We used laminated flash cards, each with a medical term printed in boldface on the top and two association words at the bottom. One of the words is meaningfully associated with the medical term and the other is not. Respondents were shown flash cards one at a time and asked to read aloud the medical term in boldface. The interviewer then read the two association words and asked which one was meaningfully associated with the medical term. Because the purpose of the association questions was to assess comprehension, respondents were instructed not to guess and say "don't know" if they did not know the correct association. The answer was deemed correct only when the respondent correctly pronounced the medical term and made the correct association. One point was scored for each correct item with a maximum score of 18. Using previously validated criteria,[19] we categorized patients as having inadequate health literacy if the SAHLPA-18 score was 1 to 14 and adequate health literacy if it was 15 to 18. Patients were considered illiterates if the SAHLPA-18 score was 0 or if individuals did not attempt to complete the test alleging being unable to read at all.

Diabetes Knowledge

Diabetes knowledge was assessed with the Spoken Knowledge in Low Literacy patients with Diabetes (SKILLD), a 10-item test with questions about behaviors patients should have to best manage their diabetes.[20] The SKILLD is verbally administrated – questions are read aloud in an open-ended format and answers are recorded as either correct of incorrect. Full marks are given only for complete answers and all the questions are weighted equally. The SKILLD was chosen because it provides measures of diabetes knowledge that are more independent of literacy status, as it does not require reading tasks and the patients are allowed to explain answers with their own words.

Diabetes Outcomes

The most recent HbA1c value extracted from the electronic medical record was used as a measure of glycemic control, for reflecting the mean glycaemia over the preceding three months. Inadequate glycemic control was defined as HbA1c $\geq$ 7%. For investigating the association of health literacy with even poorer levels glycemic control, the cutoffs $\geq$ 8% and $\geq$ 9% were adopted alternatively. The presence of diabetes complications (i.e., retinopathy, nephropathy, and neuropathy) were obtained from medical records.

Statistical Analysis

We performed descriptive statistics to characterize the sample and the studied variables. Patients were classified according to their literacy status in one of three ordered categories: illiteracy, inadequate health literacy, or adequate health literacy. Demographic variables were compared between the three groups using the Fisher exact test for categorical data, one-way analyses of variance (ANOVA) for continuous or discrete parametric data, and Kruskal-Wallis for continuous non-parametric data.

Regression analyses were used to measure the association between health literacy and glycemic control while controlling for other potentially confounding variables. In primary analyses, literacy and glycemic control were taken as categorical variables in logistic regression models. The odds of inadequate glycemic control were calculated separately for patients with illiteracy and inadequate literacy, taking patients with adequate literacy as a reference. We also used logistic regression models to determine the independent effect of health literacy on the risk of diabetes complications.

In secondary analyses, health literacy and glycemic control were used as continuous variables in multiple linear regressions. In these models HbA1c was the dependent variable, SAHLPA-18 was the primary independent variable, and other potentially confounding factors were entered as covariates. We decided to use a linear regression model after a visual inspection, but for detecting a possible nonlinear association a fractional polynomial regression was also applied.[21] Because SAHLPA-18 does not provide useful measures in illiterates, those individuals were not included in multiple linear models. In all regression models, controlled variables were age, gender, education, race, economic status, lifetime occupation, marital status, depressive symptoms, diabetes duration, treatment regimen, diabetes knowledge, and assistance for taking medications. Multicollinearity was assessed using the variance inflation factor (VIF).

Based on a two-sided significance level of 0.05 and 80% power, we estimated a total sample size of 128 patients for detecting differences between two groups with medium effect sizes (Cohen d = 0.5). Statistical analyses were performed with Stata version 12.1 (Stata Corp. LP, College Station, TX) and power calculations were conducted with the software G*Power 3.1.5.[22] All statistical tests were two-tailed, and an alpha level of less than 0.05 was used to indicate statistical significance.

RESULTS

Two hundred and twenty-five older adults with type 2 diabetes were screened for participation. Of these, 66 were ineligible because they had dementia (n=51), renal failure (n=9), did not speak fluent Portuguese (n=3), had anemia (n=2), and aphasia (n=1). All remaining 159 patients were approached at a clinical appointment. Of these, 13 were excluded because they were considered frail according to the SOF criteria, 10 presented poor visual acuity, one had severe hearing impairment, and six refused to participate.

Our sample consisted of 129 older adults with a mean age of 75.9 (±6.2) years, 69.8% of whom female. Median educational attainment was 4 years, with 14.7% of the individuals having no formal education and 82.9% having less than a high-school diploma. Health literacy below adequate as measured by the SAHLPA-18 was encountered in 56.6% of the sample – 11.6% who were illiterate and 45.0% who presented inadequate health literacy. Overall, the median duration since the diagnosis of diabetes was 10 years, 31.8% of the patients were taking insulin, and the mean HbA1c was 7.2% (±1.4). Based on the most recent results for HbA1c, 50.4% of the patients were in tight control (HbA1c <7%), 27.1% were in fair control (HbA1c 7-7.9%), 10.9% were in poor control (HbA1c 8-8.9%) and 11.6% were in very poor control (HbA1c ≥9%). Table 1 lists additional demographic and clinical characteristics of the sample.

Patients with lower literacy levels were more likely to have a non-white ethnicity, present lower scores on the economic status scale, have a manual occupation, report lower educational attainment, and have less diabetes-specific knowledge. Overall, one-way ANOVA detected difference in HbA1c means across literacy levels (p=0.034). Post hoc tests revealed a significant difference between individuals with inadequate and adequate health literacy (HbA1c 7.6 *vs* 7.0), but not between individuals who were considered illiterates and those with adequate literacy (HbA1c 6.8 *vs* 7.0).

After adjustment for potentially confounding variables, patients with inadequate health literacy were more likely than patients with adequate health literacy to present poor and very poor glycemic control, with adjusted OR = 4.76 (95% IC 1.36-16.63) for HbA1c ≥ 8% and adjusted OR = 9.19 (95% IC 1.57-53.77) for HbA1c ≥ 9%. The association between inadequate health literacy and HbA1c ≥ 7% did not reach statistical significance. Likewise, we did not find significant associations between health literacy status and diabetes complications. In all adjusted models, illiterate individuals did not have poorer diabetes outcomes when compared with individuals with adequate literacy (Table 2).

In a linear model with adjustment for confounding variables, higher levels of HbA1c were associated with lower scores on SAHLPA-18 score, lack of assistance for taking medications, and longer diabetes duration. In that model, for each one-point decrement in SAHLPA-18 score, the HbA1c increased by approximately 0.2 (Table 3). The maximum VIF was 2.1, indicating that multicollinearity was not a problem. Comparison of model fitness parameters showed that a linear regression performed as well as a second-order fractional polynomial regression (P=0.986 for comparison of deviance between both models), indicating that the relationship between SAHLPA-18 and HbA1c can be assumed to be linear in this sample.

DISCUSSION

Our study demonstrates that, in a sample of low-educated older patients with type 2 diabetes, lower scores on a health literacy test are associated with a higher likelihood of poor glycemic control after adjusting for potential confounders. Associations were stronger with higher cut-offs for defining inadequate glycemic control, suggesting that better levels of health literacy are more useful for protecting individuals from poor and very poor control than for achieving optimal targets. Our result is consistent with that reported by Tang et al.,[7] who studied a sample of Chinese patients with educational levels that are compatible with those encountered in our sample.

It has been suggested that there may be a threshold for the association between health literacy and health outcomes, i.e., a certain level of health literacy is needed for a good outcome, but higher levels add little benefit.[23] According to that rationale, the influence of health literacy on health outcomes would be stronger at the lower end of the health literacy spectrum, with the association curve tending to reach a plateau at the higher end. More studies with populations of developing countries are needed to confirm that hypothesis.

In addition to the preceding hypothesis, two additional factors can be invoked to explain the relatively strong association observed in our study between health literacy and glycemic control. First, we have made a careful selection of the sample, excluding conditions that can influence scores in health literacy tests, affect the accuracy of the HbA1c assay, or determine different targets of glycemic control. Second, the study was conducted in a government-financed health system which provides medications at no cost. This factor may attenuate inequalities in access to therapeutic resources, making the role of health literacy more evident.

After conducting a systematic review, Al Sayah et al. suggested that a confounder could explain the inconsistency in results across studies designed to investigate the effects of health literacy on diabetes outcomes.[6] Significant associations between health literacy and HbA1c were found only in studies that did not adjust for diabetes knowledge. Our study brings a new piece of evidence that is contrary to that hypothesis – we have controlled for diabetes knowledge and still have found a significant association between health literacy and glycemic control. The use of a verbally administered test to evaluate diabetes knowledge in our study may explain this contrasting result. In prior studies, tests of diabetes knowledge which involve reading and writing tasks may have provided measures that are highly correlated with those of health literacy tests, thus adding multicollinearity to the regression models.[24]

Contrary to our expectations, illiterate patients did not have poorer glycemic control when compared to patients with adequate literacy. This finding raises questions on how illiterate patients may compensate for their difficulties. We can speculate that, when caring for patients who report being unable to read, health professionals and family members are more aware of the need for compensation strategies. In contrast, among individuals who report being able to read, limited health literacy is a frequently unrecognized condition.[25] Unfortunately, our study did not include specific instruments to explore the interaction of health literacy with social support and self-efficacy in determining diabetes outcomes. In future studies such measures would better explain how illiterate patients can compensate for their difficulties.

Because the subgroup of illiterate patients was relatively small, we cannot rule out a modest difference in HbA1c levels between patients with illiteracy and adequate literacy. In a post-hoc analysis with power set at 0.80 and alpha 0.05, we calculated that our sample would be adequate to detect an effect size of 0.83, corresponding to a difference of 0.9% in mean HbA1c levels.

Our study has a number of limitations. First, its cross-sectional design does not allow the establishment of causal associations between inadequate literacy and poor diabetes outcomes. Second, although we have excluded individuals with a diagnosis of dementia, we did not screened for dementia and did not make adjustments for cognitive performance. Third, our study was clearly underpowered to investigate the association between health literacy and diabetes complications, which presented low prevalence in our sample, varying from 11.6% (neuropathy) to 13.2% (nephropathy). Fourth, although the SAHLPA-18 has been shown to be valid and present good psychometric properties in Brazilian older adults, it does not include tasks to assess some important aspects of health literacy, such as numeracy skills, interactive skills, and critical skills.

In conclusion, this study found that, in a sample of low-educated older patients with type 2 diabetes, lower health literacy skills were associated with higher odds of poor glycemic control. Contrary to our expectations, illiterate patients did not present poorer diabetes outcomes, raising the hypothesis that these individuals are more likely to have their difficulties recognized and compensated. These findings reinforce that compensation strategies may be effective and highlight the importance of identifying limited literacy in clinical practice.

AUTHOR'S ROLES

JGS participated in study design, collected data, and wrote the first draft of the manuscript. DA conceived the study, conducted statistical analysis, and wrote the final draft of the manuscript. RMM, ALB, FC, and WJF participated in study design and revised the manuscript.

CONTRIBUTORSHIP STATEMENT

JGS participated in study design, collected data, and wrote the first draft of the manuscript. DA conceived the study, conducted statistical analysis, and wrote the final draft of the manuscript. RMM, ALB, FC, and WJF participated in study design and revised the manuscript.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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Table 1. Characteristics of the sample stratified by health literacy level

		Health Literacy Level			
Characteristics	Total (n=129)	Illiterate (n=15)	Inadequate (n=58)	Adequate (n=56)	*P*-value*
Age, mean (SD), y	75.9 (6.2)	78.2 (6.3)	75.9 (5.9)	75.3 (6.4)	0.280
Female gender, No. (%)	90 (69.8)	14 (93.3)	37 (63.8)	39 (69.6)	0.074
White race, No. (%)	61 (47.9)	4 (26.7)	21 (36.2)	36 (64.3)	0.003
Education, median (IQR), y	4 (2-8)	0 (0-0)	4 (3-4)	7.5 (4-11)	<0.001
Economic level (BECC score), mean (SD)	19.9 (6.2)	16.4 (5.8)	19.2 (5.5)	21.7 (6.5)	0.006
Manual occupation, No. (%)	67 (51.9)	14 (93.3)	30 (51.7)	23 (41.1)	0.001
Married, No. (%)	42 (32.6)	1 (6.7)	19 (32.8)	22 (39.3)	0.057
Assistance with medications, No. (%)	22 (17.1)	5 (33.3)	10 (17.2)	7 (12.5)	0.200
Diabetes knowledge (SKILLD), mean (SD)	4.2 (2.6)	2.5 (2.6)	3.5 (2.2)	5.3 (2.6)	< 0.001
Health literacy (SAHLPA-18), median (IQR)	13 (10-16)	0 (0-0)	11.5 (10-13)	16 (15-17)	< 0.001
Depressive symptoms (GDS-15), median (IQR)	3 (1-5)	4 (2.3-5.8)	3 (1-5)	2 (1-4.5)	0.170
Insulin containing regimen, No. (%)	41 (31.8)	6 (40.0)	18 (31.0)	17 (30.4)	0.772
Diabetes duration, median (IQR), y	10 (5-20)	20 (7.3-20)	10 (5-19)	12 (4.5-20)	0.365
HbA1C, mean (SD)	7.2 (1.4)	6.8 (1.1)	7.6 (1.6)	7.0 (1.1)	0.034
LDL cholesterol, mean (SD)	110.5 (36.5)	105.7 (29.6)	108.3 (38.5)	114.1 (36.3)	0.605
Systolic Blood Pressure, mean (SD)	143.1 (23.5)	147.3 (23.8)	142.9 (23.7)	142.0 (23.6)	0.741
Diastolic Blood Pressure, mean (SD)	79.4 (10.8)	78.0 (12.1)	79.7 (7.9)	79.5 (13.1)	0.866
Any microvascular complication, No. (%)	33 (25.6)	3 (20.0)	18 (31.0)	12 (21.4)	0.468
Retinopathy, No. (%)	16 (12.4)	0 (0)	10 (17.2)	6 (10.7)	0.210
Nephropathy, No. (%)	17 (13.2)	1 (6.7)	9 (15.5)	7 (12.5)	0.813
Neuropathy, No. (%)	15 (11.6)	3 (20.0)	6 (10.3)	6 (10.7)	0.538
Any macrovascular complication, No. (%)	37 (28.7)	5 (33.3)	20 (34.5)	12 (21.4)	0.262
Cerebrovascular disease, No. (%)	15 (11.6)	0 (0)	10 (17.2)	5 (8.9)	0.142
Coronary artery disease, No. (%)	17 (13.2)	4 (26.7)	9 (15.5)	4 (7.1)	0.092
Peripheral artery disease, No. (%)	11 (8.5)	2 (13.3)	6 (10.3)	3 (5.4)	0.451

*The Fisher exact test was used for categorical variables, analysis of variance for means of continuous variables, and Kruskal-Wallis test for medians of continuous variables.

Abbreviations: standard deviation (SD); interquartile range (IQR); Brazilian Economic Classification Criterion (BECC); Spoken Knowledge in Low Literacy patients with Diabetes (SKILLD); 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18); 15-Item Geriatric Depression Scale (GDS-15); Hemoglobin A1c (HbA1c); Low Density Lipoprotein (LDL).

Table 2. Health literacy level and poor diabetes outcomes (n=129)

Outcome	Health Literacy Level	No. (%)	Odds Ratio (95% Confidence Interval)	
			Unadjusted	Adjusted*
HbA1C ≥ 7%	Adequate	27 (48.2)	1.00	1.00
	Inadequate	33 (56.9)	1.42 (0.68-2.97)	2.33 (0.83-6.59)
	Illiteracy	4 (26.7)	0.39 (0.11-1.38)	0.38 (0.06-2.28)
HbA1C ≥ 8%	Adequate	9 (16.1)	1.00	1.00
	Inadequate	18 (31.0)	2.35 (0.95-5.81)	4.76 (1.36-16.63)
	Illiteracy	2 (13.3)	0.80 (0.15-4.19)	1.17 (0.13-10.87)
HbA1C ≥ 9%	Adequate	3 (5.4)	1.00	1.00
	Inadequate	11 (19.0)	4.13 (1.09-15.72)	9.19 (1.57-53.77)
	Illiteracy	1 (6.7)	1.26 (0.12-13.08)	2.15 (0.11-42.64)
Retinopathy	Adequate	6 (10.7)	1.00	1.00
	Inadequate	10 (17.2)	1.74 (0.59-5.15)	2.88 (0.60-13.86)
	Illiteracy	0 (0.0)	NA	NA
Nephropathy	Adequate	7 (12.5)	1.00	1.00
	Inadequate	9 (15.5)	1.29 (0.44-3.73)	0.91 (0.19-4.42)
	Illiteracy	1 (6.7)	0.50 (0.06-4.41)	0.23 (0.01-3.85)
Neuropathy	Adequate	6 (10.7)	1.00	1.00
	Inadequate	6 (10.3)	0.96 (0.29-3.18)	0.98 (0.22-4.36)
	Illiteracy	3 (20.0)	2.08 (0.45-9.55)	1.24 (0.15-10.27)

*Adjusted for: age, gender, educational attainment, race, economic status, lifetime occupation, marital status, depressive symptoms, diabetes duration, treatment regimen, diabetes knowledge, and assistance for taking medications.
Abbreviations: not applicable (NA)

Table 3. Association between patients characteristics and HbA1c in a linear multivariate model (n=114)

	Unadjusted		Adjusted*	
Predictor	Coefficient	*P* Value	Coefficient	*P* Value
Health literacy, SAHLPA-18 score (0-18)	-0.1099	0.0075	-0.1857	0.0002
Age (years)	-0.0306	0.1562	-0.0361	0.1294
Gender (female *vs* male)	0.3013	0.2785	0.4764	0.1293
Education (years)	-0.0161	0.6077	0.0346	0.3990
Economic level, BECC score (0-34)	0.0253	0.2426	0.0338	0.1178
Race (white *vs* nonwhite)	0.3965	0.1295	-0.0864	0.7544
Lifetime occupation (manual *vs* nonmanual)	0.3444	0.1895	0.2773	0.3606
Marital status (married *vs* unmarried)	-0.2984	0.2747	-0.2364	0.4098
Depressive symptoms, GDS-15 score (0-15)	0.0214	0.6669	-0.0304	0.5366
Diabetes duration (years)	0.0335	0.0187	0.0371	0.0123
Insulin containing regimen (yes vs no)	0.6294	0.0255	0.4817	0.1041
Assistance with medications (yes vs no)	-0.5692	0.1209	-0.8753	0.0143
Diabetes knowledge, SKILLD score (0-10)	0.0485	0.3481	0.0252	0.6772

Multiple linear regression models with HbA1c as a dependent variable, SAHLPA-18 as the primary independent variable.
* Adjusted for age, gender, educational attainment, race, economic status, lifetime occupation, marital status, depressive symptoms, diabetes duration, treatment regimen, diabetes knowledge, and assistance for taking medications.
Abbreviations: 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18); Brazilian Economic Classification Criterion (BECC); 15-Item Geriatric Depression Scale (GDS-15); Spoken Knowledge in Low Literacy patients with Diabetes (SKILLD).

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1OK	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2 OK	Explain the scientific background and rationale for the investigation being reported
Objectives	3 OK	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4 OK	Present key elements of study design early in the paper
Setting	5 OK	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6 OK	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls OK *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7 OK	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8 OK	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9 OK	Describe any efforts to address potential sources of bias
Study size	10 OK	Explain how the study size was arrived at
Quantitative variables	11 OK	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12 OK	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	13 OK	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14 OK	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15 OK	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		OK *Cross-sectional study*—Report numbers of outcome events or summary measures
Main results	16 OK	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17 OK	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18 OK	Summarise key results with reference to study objectives
Limitations	19 OK	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20 OK	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21 OK	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22 OK	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Functional health literacy and glycemic control in older adults with type 2 diabetes: a cross-sectional study

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Complete List of Authors:	Souza, Jonas; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine Apolinario, Daniel; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine Magaldi, Regina; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine Busse, Alexandre; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine Campora, Flavia; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine Jacob-Filho, ; Wilson; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine

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TITLE:

Functional health literacy and glycemic control in older adults with type 2 diabetes: a cross-sectional study

Jonas Gordilho Souza[a], MD; Daniel Apolinario[a*], MD, PhD; Regina Miksian Magaldi[a], MD; Alexandre Leopold Busse[a], MD, PhD; Flavia Campora[a], MD; Wilson Jacob-Filho[a], MD, PhD

[a] Geriatrics Division, Department of Internal Medicine, University of São Paulo Medical School, São Paulo, SP, Brazil

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Health Literacy and Glycemic Control

***CORRESPONDING AUTHOR AT:**

Geriatrics Division, University of São Paulo Medical School, Av. Dr. Enéas de Carvalho Aguiar, 155, 8º Andar, Bloco 8, São Paulo, SP, CEP 05403-900, Brazil. Tel.: +55-11-30696236

E-mail address: daniel.apolinario@usp.br

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Health Literacy; Diabetes; Glycemic Control; Older Adults

ABSTRACT

OBJECTIVES: To investigate the relationship between functional health literacy and glycemic control in a heterogeneous sample of older patients with type 2 diabetes.

DESIGN: Cross-sectional study.

SETTING: A government-financed outpatient geriatric clinic in São Paulo, Brazil.

PARTICIPANTS: 129 older patients with type 2 diabetes, mean (SD) age of 75.9 (6.2) years, mean HbA1c of 7.2% (1.4), of which 14.7% had no formal education and 82.9% had less than a high-school diploma.

MEASURES: HbA1c was used as a measure of glycemic control. Functional health literacy was assessed with the 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18), a validated instrument to evaluate pronunciation and comprehension of commonly used medical terms. Regression models were controlled for demographic data, depressive symptoms, diabetes duration, treatment regimen, diabetes knowledge, and assistance for taking medications.

RESULTS: Functional health literacy below adequate was encountered in 56.6% of the sample. After controlling for potential confounding factors, patients with inadequate functional health literacy were more likely than patients with adequate functional health literacy to present poor glycemic control (OR=4.76; 95% CI 1.36-16.63). In a fully adjusted linear regression model, lower functional health literacy (β=-0.42; p<0.001), longer diabetes duration (β=0.24; p=0.012), and lack of assistance for taking medications (β=0.23; p=0.014) were associated with higher levels of HbA1c. Contrary to our expectations, illiterate patients did not have poorer outcomes when compared to patients with adequate functional health literacy, raising the hypothesis that illiterate individuals are more likely to have their difficulties recognized and compensated. However, the small subsample of illiterate patients provided limited power to reject differences with small magnitude.

CONCLUSION: Patients with inadequate functional health literacy presented higher odds of poor glycemic control. These findings reinforce the importance of identifying limited functional health literacy in clinical practice.

ARTICLE SUMMARY

Article focus

• Although many theoretical mechanisms are proposed that link health literacy to diabetes self-care, the direct association between functional health literacy and glycemic control is still controversial.

• In particular, there is paucity of data on the relationship between health literacy and glycemic control at the very low end of the health literacy spectrum.

Key messages

• Older patients with inadequate functional health literacy were more likely to present poor glycemic control when compared to patients with adequate functional health literacy, but illiterate patients did not present a higher risk of poor glycemic control.

• We hypothesize that individuals who report being unable to read are more likely to have their difficulties recognized and compensated. In contrast, among individuals who report being able to read, limited functional health literacy is frequently unrecognized and less likely to be compensated.

Strengths and limitations of this study

• A wide range of potentially confounding variables has been controlled, including depression, diabetes duration, treatment regimen, diabetes knowledge, and assistance for taking medications.

• The relatively small subsample of illiterate patients provided limited power to reject risk differences with small magnitude. Thus, these preliminary findings should be confirmed in further studies.

INTRODUCTION

Health literacy has been defined by the World Health Organization as " the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand and use information in ways which promote and maintain good health".[1] The concept of health literacy is not restricted to the ability to read and follow medical instructions. It includes a range of communicative and critical skills such as searching for specific health knowledge, evaluating information for credibility, balancing risks and benefits, expressing needs, and negotiating preferences.

The term "functional health literacy" has been used to imply one's ability to function adequately in health care settings, as determined by instruments which access basic skills needed to deal with health-related written materials.[2] This somewhat narrow approach misses the richness implied by the WHO definition, but warrants practical feasibility for studies investigating the relationships between health literacy and health outcomes. Inadequate functional health literacy has been independently associated with poorer ability to take medications appropriately, lower utilization of preventive services, more hospitalizations, poorer overall health status, and higher mortality rates.[3] Multiple interventions exist to lessen the negative effects of inadequate functional health literacy,[4] but health professionals often overestimate patients' abilities and fail to recognize the problem.[5]

Some segments of the population are at greater risk for inadequate health literacy, including the socioeconomically disadvantaged, immigrants, and older adults. In a study that included Medicare enrollees aged 65 years and older, functional health literacy skills declined dramatically with age, even after adjusting for educational status and cognitive impairment.[6] Inadequate health literacy may disproportionately affect the health of older persons, not only because it is more prevalent in this age group, but also

because older persons are more exposed to health care services and more likely to receive complex therapeutic regimens.[7]

Diabetes care involves extensive self-management behaviors and requires pharmacological regimens that tend to become increasingly complex over time. This prototypical chronic disease constitutes a representative model for studying the influence of health literacy on health outcomes. However, although many theoretical mechanisms are proposed that link health literacy to diabetes self-care and clinical outcomes, the direct association between functional health literacy and glycemic control is still controversial.[8]

In a recent systematic review, 13 studies were included that have explored the relationship between health literacy and glycemic control.[9] Results were inconsistent across studies, and the heterogeneity did not allow the estimation of an overall effect. Therefore, the evidence for direct association was rated insufficient. These findings may indicate that health literacy is related to certain outcomes in particular populations, but not in others. Only one study was conducted in a developing country, including a population with a very low levels educational attainment.[10] In that study, higher scores on the Short Test of Functional Health Literacy in Adults (S-TOFHLA) were strongly associated with reduced levels of glycosylated hemoglobin. In general, there is paucity of data at the very low end of the literacy status spectrum. In particular, no studies have examined the association between health literacy and glycemic control in patients who have only rudimentary reading skills and in those who are unable to read at all.

The purpose of this study was to determine the independent association of functional health literacy with glycemic control in a Brazilian sample of heterogeneous, predominantly low-educated older adults with type 2 diabetes.

METHODS

Subjects

A convenience sample was recruited between June 2011 and July 2012 from a government-financed outpatient geriatric clinic in the city of São Paulo, southeastern Brazil. During this period, 225 older adults with type 2 diabetes were screened for participation. At the time of the study, there was no diabetes management program or educational intervention in place. All patients were treated by geriatricians or geriatricians in training, were provided diabetes medications at no cost, and had access to the same range of services.

Research staff reviewed medical records and spoke with patients to verify inclusion and exclusion criteria. Eligibility criteria included: (1) age ≥ 60 years; (2) self-reported ability to speak fluent Portuguese; (3) type 2 diabetes currently being treated with daily medication; and (4) a glycosylated hemoglobin (HbA1c) measurement performed within a 6 month period. Patients were ineligible if they had a hearing, vision, motor or speech problem that precluded adequate interaction with the interviewer or impeded appropriate completion of the proposed assessments. Patients with a diagnosis of dementia were excluded because cognitive impairment has been associated with poor performance in functional health literacy tests and may affect an individual's ability to manage drug regimens.[11,12] Patients with overt thyroid dysfunction (thyroid-stimulating hormone < 0.1 or > 10mU/L), anemia (hemoglobin < 11 mg/dL for men and < 10 mg/dL for women), and severe renal failure (estimated glomerular filtration rate < 30ml/min/1.73m^2) were excluded because these conditions can affect the accuracy of the HbA1c assay.[13-15]

We further excluded subjects who fulfilled criteria for frailty, because less stringent targets of glycemic control have been proposed for frail elderly.[16] Frailty status

was determined according to the Study of Osteoporotic Fracture (SOF) index.[17] The SOF index is composed of following three items: (1) weight loss of more than 5% during the last year; (2) inability to rise from a chair five consecutive times without using the arms; and (3) self-perceived reduced energy level. Subjects were assessed systematically and excluded if at least two of the three criteria were fulfilled.

The research protocol was approved by the local ethics committee. Eligible patients attending to scheduled appointments were approached in the clinic waiting room and provided a description of the study procedures. An informed consent was obtained before the interview. The consent form was read aloud and explained in plain language for those individuals who declared to be illiterate or were judged by the interviewer as having questionable capacity to understand the form.

Demographic and Clinical Data

All participants were interviewed for demographic information, including age, gender, educational attainment (highest grade completed), race (white or non-white), and lifetime occupation (predominantly manual or non-manual). Individuals were further classified as married (including cohabiting) or unmarried (never married, divorced or widowed). Economic status was determined according to the Brazilian Economic Classification Criterion,[18] which provides a discrete scale calculated by assigning scores to the number of household assets.

Duration of diabetes was registered and treatment was characterized as oral agents alone or an insulin-containing regimen. Participants were further asked if they had supervision or help taking medications and classified as receiving assistance or not. Because some studies have reported depression as an important factor influencing glycemic control,[19] we assessed depressive symptoms using the 15-Item Geriatric Depression Scale (GDS-15).[20,21]

Functional Health Literacy

We assessed functional health literacy by using the 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18), a test which evaluates pronunciation and comprehension of commonly used medical terms. The SAHLPA-18 has been previously validated in a sample of Brazilian older adults, presenting moderate to high correlations with construct criteria, high internal consistency, and adequate test-retest reliability.[22]

We used laminated flash cards, each with a medical term printed in boldface on the top and two association words at the bottom. One of the words is meaningfully associated with the medical term and the other is not. Respondents were shown flash cards one at a time and asked to read aloud the medical term in boldface. The interviewer then read the two association words and asked which one was meaningfully associated with the medical term. Because the purpose of the association questions was to assess comprehension, respondents were instructed not to guess and say "don't know" if they did not know the correct association. The answer was deemed correct only when the respondent correctly pronounced the medical term and made the correct association. One point was scored for each correct item with a maximum score of 18. Using previously validated criteria,[22] we categorized patients as having inadequate functional health literacy if the SAHLPA-18 score was 1 to 14 and adequate functional health literacy if it was 15 to 18. Patients were considered illiterates if the SAHLPA-18 score was 0 or if individuals did not attempt to complete the test alleging being unable to read at all.

Diabetes Knowledge

Diabetes knowledge was assessed with the Spoken Knowledge in Low

Literacy patients with Diabetes (SKILLD), a 10-item test with questions about behaviors patients should have to best manage their diabetes.[23] The SKILLD is verbally administrated – questions are read aloud in an open-ended format and answers are recorded as either correct or incorrect. Full marks are given only for complete answers and all the questions are weighted equally. The SKILLD was chosen because it provides measures of diabetes knowledge that are more independent of literacy status, as it does not require reading tasks and the patients are allowed to explain answers with their own words.

Diabetes Outcomes

The most recent HbA1c value extracted from the electronic medical record was used as a measure of glycemic control, reflecting the mean glycaemia over the preceding two to three months. Recently published guidelines from the American Geriatrics Society Expert Panel on the Care of Older Adults with Diabetes Mellitus recommend that the "target goal for HbA1c in older adults generally should be 7.5 to 8.0%".[16] Accordingly, inadequate glycemic control was defined as HbA1c > 8%. Data on diabetes complications (i.e., retinopathy, nephropathy, and neuropathy) were obtained from the medical records and registered as dichotomous variables (present or absent).

Statistical Analysis

We performed descriptive statistics to characterize the sample and the studied variables. Patients were classified according to their functional health literacy status in one of three categories: illiteracy, inadequate functional health literacy, or adequate functional health literacy. Variables were compared between the three groups using the Fisher exact test for categorical data, one-way analyses of variance (ANOVA) for continuous parametric data, and Kruskal-Wallis for continuous non-parametric data.

Post hoc tests for determining differences between means were accomplished with the Tukey's honestly significant difference procedure. Effect sizes were calculated using Cohen's d method.

Regression analyses were used to explore the association between functional health literacy and glycemic control while controlling for other potentially confounding variables. In primary analyses, functional health literacy and glycemic control were used as continuous variables in hierarchical multiple linear regressions. In these models HbA1c was the dependent variable and the SAHLPA-18 was the primary independent variable. Covariates were entered in four sequential steps for examining their incremental validity, as indicated by changes in the coefficient of determination (R^2). In the first step the SAHLPA-18 was entered without covariates. In the second step, seven socio-demographic variables were entered as a block (i.e., age, gender, race, educational attainment, occupation, economic status, and marital status). The incremental role of four clinical variables was examined on the third step (i.e., depressive symptoms, diabetes duration, treatment regimen, and assistance for taking medications). The SKILLD was entered as the last step, because diabetes knowledge represents a further adjustment factor deemed to be interrelated with health literacy and that has not been used as a covariate in many studies. Because SAHLPA-18 does not provide useful measures in illiterates, those individuals were not included in multiple linear models. We decided to use a linear regression model after a visual inspection, but a fractional polynomial regression was also applied to detect a possible nonlinear association.[24] Because regression models have included a substantial number of correlated variables, multicollinearity was assessed using the variance inflation factor (VIF).

In secondary analyses, functional health literacy and glycemic control were taken as categorical variables in logistic regression models. The odds of inadequate glycemic control were calculated separately for patients with illiteracy and inadequate functional health literacy, taking patients with adequate functional health literacy as a reference. We also used logistic regression models to determine the independent effect of functional health literacy on the risk of diabetes complications. .

Two-way interactions were carried out to investigate whether the impact of functional health literacy on glycemic control differ according to age, gender, depressive symptoms, diabetes duration, insulin use, and assistance for taking medications. In addition, we have investigated interactions in the fully adjusted linear regression model between all the significant variables.

Based on a two-sided significance level of 0.05 and 80% power, we estimated a total sample size of 128 patients for detecting differences between two groups with medium effect sizes (Cohen's d = 0.5). Statistical analyses were performed with Stata version 12.1 (Stata Corp. LP, College Station, TX) and power calculations were conducted with the software G*Power 3.1.5.[25] All statistical tests were two-tailed, and an alpha level of less than 0.05 was used to indicate statistical significance.

RESULTS

Two hundred and twenty-five older adults with type 2 diabetes were screened for participation. Of these, 66 were ineligible because they had dementia (n=51), renal failure (n=9), did not speak fluent Portuguese (n=3), had anemia (n=2), and aphasia (n=1). All remaining 159 patients were approached at a clinical appointment. Of these, 13 were excluded because they were considered frail according to the SOF criteria, 10 presented poor visual acuity, one had severe hearing impairment, and six refused to participate.

Our sample consisted of 129 older adults with a mean age (SD) of 75.9 (6.2) years, 69.8% of whom female. Median educational attainment was 4 years, with 14.7% of the individuals having no formal education and 82.9% having less than a high-school diploma. Functional health literacy below adequate as measured by the SAHLPA-18 was encountered in 56.6% of the sample – 11.6% who were illiterate and 45.0% who presented inadequate functional health literacy. Overall, the median duration since the diagnosis of diabetes was 10 years, 31.8% of the patients were taking insulin, and the mean (SD) HbA1c was 7.2% (1.4). Based on the most recent results for HbA1c, 52.7% of the patients were in tight control (HbA1c ≤7%), 24.8% were in fair control (HbA1c 7.1-8%), and 22.5% presented inadequate glycemic control (HbA1c >8%). Table 1 lists additional demographic and clinical characteristics of the sample.

Patients with lower functional health literacy levels were more likely to have a non-white ethnicity, present lower economic status, have a manual occupation, report lower educational attainment, and have less diabetes-specific knowledge. Overall, one-way ANOVA detected a significant difference in HbA1c means across functional health literacy levels (p=0.034). Post hoc tests revealed a significant difference between individuals with adequate and inadequate functional health literacy (HbA1c 6.96 *vs* 7.56; p=0.049), with a Cohen's d of 0.44 indicating a medium effect size.[26] There was no difference in glycemic control between individuals with adequate functional health literacy and those who were considered illiterates (HbA1c 6.96 *vs* 6.85; p=0.953).

In linear regression models, lower SAHLPA-18 scores were associated with higher levels of HbA1c throughout all adjustment steps. In the fully adjusted model, the SAHLPA-18 was the variable more strongly associated with glycemic control, with a standardized beta of -0.42 (p<0.001). This means that, with all other variables held constant, a one SD increase on the SAHLPA-18 would be associated with an improvement of 0.42 SD (0.6%) on the predicted HbA1c. The other variables associated with a poorer glycemic control in the fully adjusted model were lack of assistance for taking medications, and longer diabetes duration (Table 2). The maximum VIF was 2.11 and mean VIF was 1.46, indicating that multicollinearity was not a problem. Comparison of model fitness parameters showed that a linear regression performed as well as a second-order fractional polynomial regression (*P*=0.986), indicating that the relationship between SAHLPA-18 and HbA1c can be assumed to be linear in this sample. Interaction analyses did no yield any significant effects.

In fully adjusted logistic regression models, patients with inadequate functional health literacy were more likely than patients with adequate functional health literacy to present inadequate glycemic control (HbA1c >8%), with adjusted odds ratio of 4.76 (95% CI 1.36-16.63). . We did not find significant associations between inadequate functional health literacy and diabetes complications. In all adjusted models, illiterate individuals did not have poorer diabetes outcomes when compared with individuals with adequate functional health literacy (Table 3).

DISCUSSION

In a sample of low-educated older patients with type 2 diabetes, our study demonstrates that lower scores on a functional health literacy test are associated with a higher likelihood of poor glycemic control after adjusting for potential confounders. Our result is consistent with that reported by Tang et al.,[10] who studied a sample of Chinese patients with educational levels that are compatible with those encountered in our sample.

It has been suggested that there may be a threshold for the association between health literacy and health outcomes, i.e., a certain level of health literacy is needed for a good outcome, but higher levels add little benefit.[27] According to that rationale, the influence of health literacy on health outcomes would be stronger at the lower end of the health literacy spectrum, with the association curve tending to reach a plateau at the higher end. Our study, as well as that of Tang et al.,[10] has included a sample which represents properly the lowest levels of the health literacy spectrum, where the association of health literacy with health outcomes is deemed to be stronger. This may explain, at least in part, the convincing associations that have been found in both studies, but more studies with very low educated populations from developing countries are needed to confirm that hypothesis.

In addition to the preceding hypothesis, two additional factors can be invoked to explain the significant association observed in our study between functional health literacy and glycemic control. First, we have made a careful selection of the sample, excluding conditions that can influence scores in functional health literacy tests, affect the accuracy of the HbA1c assay, or determine different targets of glycemic control. Second, the study was conducted in a government-financed health system which provides medications at no cost. This factor may attenuate inequalities in access to therapeutic resources, making the role of functional health literacy more evident.

After conducting a systematic review, Al Sayah et al. suggested that a confounder could explain the inconsistency in results across studies designed to investigate the effects of health literacy on diabetes outcomes.[9] Significant associations between functional health literacy and HbA1c were found only in studies that did not adjust for diabetes knowledge. Our study brings a new piece of evidence that is contrary to that hypothesis – we have controlled for diabetes knowledge and still have found a significant association between functional health literacy and glycemic control. The use of a verbally administered test to evaluate diabetes knowledge in our study may explain this contrasting result. In prior studies, tests of diabetes knowledge which involve reading and writing may have provided measures that are highly correlated with functional health literacy tests, thus suppressing some of the effects of this variable.

In our study the diabetes knowledge test was only moderately correlated with the measure of functional health literacy (r=0.39) and its corresponding VIF was 1.70, indicating that it did not cause multicollinearity. When the SKILLD was added to a model already containing the SAHLPA-18, demographic characteristics, and clinical factors, it was not significantly associated with functional health literacy, it did not change the results, and did not improve predictive power of the regression model (Table 2). Findings from a recent study conducted by Jeppesen et al. have raised concerns about the properties of the SKILLD.[28] Besides presenting only a moderate correlation with a measure of criterion validity, the test has been shown to have limited inter-rater reliability and low internal consistence. Taking in account the findings of Jeppesen et al. and those of the present study, it is worthy to suggest that the properties of the SKILLD should be carefully investigated in future studies before it can be assumed to provide valid and useful measures.

Contrary to our expectations, illiterate patients did not have poorer glycemic control when compared to patients with adequate functional health literacy. This finding raises questions on how illiterate patients may compensate for their difficulties. We can speculate that, when caring for patients who report being unable to read at all, health professionals and family members are more aware of the need for compensation strategies. In contrast, among individuals who report being able to read, inadequate health literacy is a frequently unrecognized condition.[5] Unfortunately, our study did not include a specific instrument to assess social support, what would have allowed us to explore a possible interaction of this factor with functional health literacy in determining diabetes outcomes. In future studies instruments designed to assess social support may possibly explain how illiterate patients can compensate for their difficulties.

In an Iranian diabetes clinic, Jahanlou and Karami did not find a significant difference in HbA1c levels between illiterate (n=108) and literate (n=148) patients.[29] Similarly, Hawthorne and Tomlinson reported comparable levels of HbA1c between illiterate (n=54) and literate (n=158) Pakistani patients with type 2 diabetes.[30] However, both studies have based their reports on bivariate analyses, without appropriate control for confounding variables. In our study, the relatively small subsample of illiterate patients provided limited power to reject differences with small or even moderate magnitude. Therefore, these preliminary findings regarding glycemic control in illiterate patients should be confirmed in future studies with adequate sample size and adjustment for confounding variables.

Our study has a number of limitations. First, its cross-sectional design does not allow the establishment of causal associations between inadequate functional health literacy and poor diabetes outcomes. Second, although we have excluded individuals with a diagnosis of dementia, we did not screen for dementia and did not make adjustments for cognitive performance. Third, our study was clearly underpowered to investigate the association between functional health literacy and diabetes complications, which presented low prevalence in our sample, varying from 11.6% (neuropathy) to 13.2% (nephropathy). Fourth, although the SAHLPA-18 has been shown to be valid and present good psychometric properties in Brazilian older adults,[22] it does not include tasks to assess some important aspects of health literacy, such as numeracy skills, interactive skills, and critical skills.[31]

In conclusion, this study found that, in a sample of low-educated older patients with type 2 diabetes, lower functional health literacy skills were associated with higher odds of poor glycemic control. These findings reinforce the importance of identifying limited functional health literacy in clinical practice.

CONTRIBUTORS

JGS participated in study design, collected data, and wrote the first draft of the manuscript. DA conceived the study, conducted statistical analysis, and wrote the final draft of the manuscript. RMM, ALB, FC, and WJF participated in study design and revised the manuscript.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

DATA SHARING STATEMENT

No unpublished data from the study are available

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Table 1. Characteristics of the sample stratified by functional health literacy level

		Functional Health Literacy Level			
Characteristics	Total (n=129)	Illiterate (n=15)	Inadequate (n=58)	Adequate (n=56)	*P*-value*
Age, mean (SD), y	75.9 (6.2)	78.2 (6.3)	75.9 (5.9)	75.3 (6.4)	0.280
Female gender, No. (%)	90 (69.8)	14 (93.3)	37 (63.8)	39 (69.6)	0.074
White race, No. (%)	61 (47.9)	4 (26.7)	21 (36.2)	36 (64.3)	0.003
Education, median (IQR), y	4 (2-8)	0 (0-0)	4 (3-4)	7.5 (4-11)	<0.001
Economic level (BECC score), mean (SD)	19.9 (6.2)	16.4 (5.8)	19.2 (5.5)	21.7 (6.5)	0.006
Manual occupation, No. (%)	67 (51.9)	14 (93.3)	30 (51.7)	23 (41.1)	0.001
Married, No. (%)	42 (32.6)	1 (6.7)	19 (32.8)	22 (39.3)	0.057
Assistance with medications, No. (%)	22 (17.1)	5 (33.3)	10 (17.2)	7 (12.5)	0.200
Diabetes knowledge (SKILLD), mean (SD)	4.2 (2.6)	2.5 (2.6)	3.5 (2.2)	5.3 (2.6)	< 0.001
Health literacy (SAHLPA-18), median (IQR)	13 (10-16)	0 (0-0)	11.5 (10-13)	16 (15-17)	< 0.001
Depressive symptoms (GDS-15), median (IQR)	3 (1-5)	4 (2.3-5.8)	3 (1-5)	2 (1-4.5)	0.170
Insulin containing regimen, No. (%)	41 (31.8)	6 (40.0)	18 (31.0)	17 (30.4)	0.772
Diabetes duration, median (IQR), y	10 (5-20)	20 (7.3-20)	10 (5-19)	12 (4.5-20)	0.365
HbA1C, mean (SD)	7.2 (1.4)	6.8 (1.1)	7.6 (1.6)	7.0 (1.1)	0.034
LDL cholesterol, mean (SD)	110.5 (36.5)	105.7 (29.6)	108.3 (38.5)	114.1 (36.3)	0.605
Systolic Blood Pressure, mean (SD)	143.1 (23.5)	147.3 (23.8)	142.9 (23.7)	142.0 (23.6)	0.741
Diastolic Blood Pressure, mean (SD)	79.4 (10.8)	78.0 (12.1)	79.7 (7.9)	79.5 (13.1)	0.866
Any microvascular complication, No. (%)	33 (25.6)	3 (20.0)	18 (31.0)	12 (21.4)	0.468
Retinopathy, No. (%)	16 (12.4)	0 (0)	10 (17.2)	6 (10.7)	0.210
Nephropathy, No. (%)	17 (13.2)	1 (6.7)	9 (15.5)	7 (12.5)	0.813
Neuropathy, No. (%)	15 (11.6)	3 (20.0)	6 (10.3)	6 (10.7)	0.538
Any macrovascular complication, No. (%)	37 (28.7)	5 (33.3)	20 (34.5)	12 (21.4)	0.262
Cerebrovascular disease, No. (%)	15 (11.6)	0 (0)	10 (17.2)	5 (8.9)	0.142
Coronary artery disease, No. (%)	17 (13.2)	4 (26.7)	9 (15.5)	4 (7.1)	0.092
Peripheral artery disease, No. (%)	11 (8.5)	2 (13.3)	6 (10.3)	3 (5.4)	0.451

*The Fisher exact test was used for categorical variables, analysis of variance for means of continuous variables, and Kruskal-Wallis test for medians of continuous variables.

Abbreviations: standard deviation (SD); interquartile range (IQR); Brazilian Economic Classification Criterion (BECC); Spoken Knowledge in Low Literacy patients with Diabetes (SKILLD); 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18); 15-Item Geriatric Depression Scale (GDS-15); Hemoglobin A1c (HbA1c); Low Density Lipoprotein (LDL).

Table 2. Association between HbA1c and patient characteristics in hierarchical multiple linear regression models (n=114)

	Standardized beta coefficients			
Independent Variables	**Step 1** *R^2=0.06*	**Step 2** *R^2=0.15*	**Step 3** *R^2=0.29*	**Step 4** *R^2=0.29*
Health literacy, SAHLPA-18 score	-0.25**	-0.31**	-0.41***	-0.42***
Age (years)		-0.16	-0.16	-0.16
Gender (female *vs* male)		0.08	0.16	0.16
Race (white *vs* nonwhite)		0.03	0.03	0.03
Education (years)		0.11	0.12	0.10
Occupation (manual *vs* non-manual)		0.14	0.11	0.10
Economic status (BECC score)		0.16	0.15	0.15
Marital status (married *vs* unmarried)		-0.09	-0.08	-0.08
Depressive symptoms, GDS-15 score			-0.07	-0.06
Diabetes duration (years)			0.25**	0.24*
Insulin containing regimen (yes *vs* no)			0.17	0.16
Assistance with medications (yes *vs* no)			-0.22*	-0.23*
Diabetes knowledge, SKILLD score				0.05

Multiple linear regression models with HbA1c as the dependent variable, SAHLPA-18 as the primary independent variable, and other characteristics as covariates. The coefficient of determination (R^2) indicates the proportion of the variance of the HbA1c which can be explained by the set of predictors.
Abbreviations: 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18); Brazilian Economic Classification Criterion (BECC); 15-Item Geriatric Depression Scale (GDS-15); Spoken Knowledge in Low Literacy patients with Diabetes (SKILLD).
*P<0.05
**p<0.01
***p<0.001

Table3. Functional health literacy and poor diabetes outcomes (n=129)

Outcome	Health Literacy Level	No. (%)	Odds Ratio (95% Confidence Interval)	
			Unadjusted	Adjusted*
Inadequate Glycemic Control (HbA1C > 8%)	Adequate	9 (16.1)	1.00	1.00
	Inadequate	18 (31.0)	2.35 (0.95-5.81)	4.76 (1.36-16.63)
	Illiteracy	2 (13.3)	0.80 (0.15-4.19)	1.17 (0.13-10.87)
Retinopathy	Adequate	6 (10.7)	1.00	1.00
	Inadequate	10 (17.2)	1.74 (0.59-5.15)	2.88 (0.60-13.86)
	Illiteracy	0 (0.0)	NA	NA
Nephropathy	Adequate	7 (12.5)	1.00	1.00
	Inadequate	9 (15.5)	1.29 (0.44-3.73)	0.91 (0.19-4.42)
	Illiteracy	1 (6.7)	0.50 (0.06-4.41)	0.23 (0.01-3.85)
Neuropathy	Adequate	6 (10.7)	1.00	1.00
	Inadequate	6 (10.3)	0.96 (0.29-3.18)	0.98 (0.22-4.36)
	Illiteracy	3 (20.0)	2.08 (0.45-9.55)	1.24 (0.15-10.27)

*Adjusted for: age, gender, race, educational attainment, occupation, economic status, marital status, assistance for taking medications, depressive symptoms, diabetes duration, treatment regimen, and diabetes knowledge.
Abbreviation: not applicable (NA)

TITLE:

~~Limited~~ Functional health literacy~~, but not illiteracy, is associated with inadequate~~ and glycemic control in older adults with type 2 diabetes: a cross-sectional study

Jonas Gordilho Souza[a], MD; Daniel Apolinario[a*], MD, PhD; Regina Miksian Magaldi[a], MD; Alexandre Leopold Busse[a], MD, PhD; Flavia Campora[a], MD; Wilson Jacob-Filho[a], MD, PhD

[a] Geriatrics Division, Department of Internal Medicine, University of São Paulo Medical School, São Paulo, SP, Brazil

RUNNING TITLE:

Health Literacy and Glycemic Control

***CORRESPONDING AUTHOR AT:**

Geriatrics Division, University of São Paulo Medical School, Av. Dr. Enéas de Carvalho Aguiar, 155, 8º Andar, Bloco 8, São Paulo, SP, CEP 05403-900, Brazil. Tel.: +55-11-30696236

E-mail address: daniel.apolinario@usp.br

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KEYWORDS:

Health Literacy; Diabetes; Glycemic Control; Older Adults

ABSTRACT

OBJECTIVES: To investigate the relationship between functional health literacy and glycemic control in a heterogeneous sample of older patients with type 2 diabetes.

DESIGN: Cross-sectional study.

SETTING: A government-financed outpatient geriatric clinic in São Paulo, Brazil.

PARTICIPANTS: 129 older patients with type 2 diabetes, mean (SD) age of 75.9 (~~±~~6.2) years, mean HbA1c of 7.2% (~~±~~1.4), of which 14.7% had no formal education and 82.9% had less than a high-school diploma.

MEASURES: HbA1c was used as a measure of glycemic control. Functional ~~H~~health literacy was assessed with the 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18), a validated instrument to evaluate pronunciation and comprehension of commonly used medical terms. Regression models were controlled for ~~extensive~~ demographic data, depressive symptoms, diabetes duration, treatment regimen, diabetes knowledge, and assistance for taking medications.

RESULTS: Functional ~~H~~health literacy below adequate was encountered in 56.6% of the sample. After controlling for potential confounding factors, ~~P~~patients with inadequate functional health literacy were more likely than patients with adequate functional health literacy to present poor glycemic control (OR=4.76; 95% CI 1.36-16.63). ~~Adjusted OR for HbA1c ≥8 was 4.76 (95%IC 1.36-16.63) and adjusted OR for HbA1c ≥ 9% was 9.19 (95%IC 1.57-53.77). Illiterate individuals did not have poorer diabetes outcomes.~~ In a fully adjusted ~~multivariate~~ linear regression model, ~~adjusted for confounding variables, higher levels of HbA1c were associated with~~ lower functional health literacy ~~levels~~ (β=-0.42; p<0.001), longer diabetes duration (β=0.24; p=0.012), and lack of assistance for taking medications (β=0.23; p=0.014) were associated with higher levels of HbA1c. Contrary to our expectations, illiterate patients did not have poorer outcomes when compared to patients with adequate functional health literacy, raising the hypothesis that ~~these~~illiterate individuals ~~individuals~~ are more likely to have their difficulties recognized and compensated. However, the small subsample of illiterate patients provided limited power to reject differences with small magnitude.

CONCLUSION: Patients with inadequate functional health literacy presented higher odds of poor glycemic control. ~~Contrary to our expectations, illiterate patients did not have poorer outcomes, raising the hypothesis that these individuals are more likely to have their difficulties recognized and compensated.~~ These findings reinforce the importance of identifying limited functional health literacy in clinical practice.

ARTICLE SUMMARY

Article focus

• Although many theoretical mechanisms are proposed that link health literacy to diabetes self-care, the direct association between functional health literacy and glycemic control is still controversial.

• In particular, ~~no studies have compared glycemic control between patients who have inadequate levels of literacy and those who are unable to read at all~~ there is paucity of data on the relationship between health literacy and glycemic control at the very low end of the health literacy spectrum.

Key messages

• Older patients with inadequate functional health literacy were more likely to present poor glycemic control when compared to patients with adequate functional health literacy, but illiterate patients did not present a higher risk of poor glycemic control.

• We hypothesize that ~~I~~individuals who report~~ed~~ being unable to read ~~at all~~ are ~~probably~~ more likely to have their difficulties recognized and compensated. In contrast, among individuals who report being able to read, limited functional health literacy is ~~a~~ frequently unrecognized and less likely to be compensated.

Strengths and limitations of this study

• A wide range of potentially confounding variables has been controlled, including depression, diabetes duration, treatment regimen, diabetes knowledge, and assistance for taking medications.

• The relatively small subsample of illiterate patients provided limited power to reject risk differences with small magnitude. Thus, these preliminary findings should be confirmed in further studies.

INTRODUCTION

Health literacy has been defined by the World Health Organization as "~~the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions~~ the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand and use information in ways which promote and maintain good health".[1] The concept of health literacy is not restricted to the ability ~~of~~ to read~~ing~~ and follow medical instructions~~prescriptions and calculating dosages~~. It includes a range of communicative and critical skills such as searching for specific health knowledge, evaluating information for credibility, ~~analyzing~~ balancing risks and benefits, ~~communicating~~expressing needs, and negotiating preferences.

The term "functional health literacy" has been used to imply one's ability to function adequately in health care settings, as determined by instruments which access basic skills needed to deal with health-related written materials.[2] This somewhat narrow approach misses the richness implied by the WHO definition, but warrants practical feasibility for studies investigating the relationships between health literacy and health outcomes. Inadequate functional health literacy has been independently associated with poorer ability to take medications appropriately, lower utilization of preventive services, more hospitalizations, poorer overall health status, and higher mortality rates.[~~2~~3] Multiple interventions exist to lessen the negative effects of inadequate functional health literacy,[4] but health professionals often overestimate patients' abilities and fail to recognize the problem.[5]

Some segments of the population are at greater risk for inadequate health literacy, including the socioeconomically disadvantaged, immigrants, and older adults. In a study that included Medicare enrollees aged 65 years and older, functional health literacy skills declined dramatically with age, even after adjusting for educational status and cognitive impairment.[~~3~~6] Inadequate health literacy may disproportionately affect the health of older persons, not only because it is more prevalent in this age group, but also because older persons are more exposed to health care services and more likely to receive complex therapeutic regimens.[~~4~~7]

Diabetes care involves extensive self-management behaviors and requires pharmacological regimens that tend to become increasingly complex over time. ~~It is a~~This prototypical chronic disease ~~which~~ constitutes a representative model for studying the influence of health literacy on health outcomes. However, although many theoretical mechanisms are proposed that link health literacy to diabetes self-care and clinical outcomes, the direct association between functional health literacy and glycemic control is still controversial.[~~5~~8]

In a recent systematic review, 13 studies were included that have explored the relationship between health literacy and glycemic control.[~~6~~9] Results were inconsistent across studies, and the heterogeneity did not allow the estimation of an overall effect. Therefore, the evidence for direct association was rated insufficient. These findings may indicate that health literacy is related to certain outcomes in particular populations, but not in others. Only one study was conducted in a developing country, including a population with a very low levels educational attainment.[~~7~~10] In that study, higher scores on the Short Test of Functional Health Literacy in Adults (S-TOFHLA) were strongly associated with reduced levels of glycosylated hemoglobin. In general, there is paucity of data at the very low end of the literacy status spectrum. In particular, no studies have ~~compared~~examined the association between health literacy and glycemic control ~~between~~in patients who have only rudimentary ~~levels of literacy~~reading skills and in those who are unable to read at all.

The purpose of this study was to determine the independent ~~contribution~~association of functional health literacy ~~to~~with glycemic control in a Brazilian ~~population~~sample of heterogeneous, predominantly low-educated ~~of~~ older adults with type 2 diabetes.

METHODS

Subjects

A convenience sample was recruited between June 2011 and July 2012 from a government-financed outpatient geriatric clinic in the city of São Paulo, southeastern Brazil. During this period, 225 older adults with type 2 diabetes were screened for participation. At the time of the study, there was no diabetes management program or educational intervention in place. All patients were treated by geriatricians or geriatricians in training, were provided diabetes medications at no cost, and had access to the same range of services.

Research staff reviewed medical records and spoke with patients to verify inclusion and exclusion criteria. ~~To be eligible, the subject had to meet the following criteria~~Eligibility criteria included: (1) age ≥ 60 years; (2) self-reported ability to speak fluent Portuguese; (3) type 2 diabetes currently being treated with daily medication; and (4) a glycosylated hemoglobin (HbA1c) measurement performed within a 6 month period. Patients were ineligible if they had a hearing, vision, motor or speech problem that precluded adequate interaction with the interviewer or impeded appropriate completion of the proposed assessments. Patients with a diagnosis of dementia were excluded because cognitive impairment has been associated with poor performance in functional health literacy tests and may affect an individual's ability to manage drug regimens.[~~8~~11,~~9~~12] Patients with overt thyroid dysfunction (thyroid-stimulating hormone <

0.1 or > 10mU/L), anemia (hemoglobin < 11 mg/dL for men and < 10 mg/dL for women), and severe renal failure (estimated glomerular filtration rate < 30ml/min/1.73m^2) were excluded because these conditions can affect the accuracy of the HbA1c assay.[~~10~~13-~~12~~15]

We further excluded subjects who fulfilled criteria for frailty, because less stringent targets of glycemic control have been proposed for frail elderly.[~~13~~16] Frailty status was determined according to the Study of Osteoporotic Fracture (SOF) index.[~~14~~17] The SOF index is composed of following three items: (1) weight loss of more than 5% during the last year; (2) inability to rise from a chair five consecutive times without using the arms; and (3) self-perceived reduced energy level.~~, evaluated by the question “do you feel full of energy?”~~ Subjects were assessed systematically and excluded if at least two of the three criteria were fulfilled.

The research protocol was approved by the local ethics committee. Eligible patients attending to scheduled appointments were approached in the clinic waiting room and provided a description of the study procedures. An informed consent was obtained before the interview. The consent form was read aloud and explained in plain language for those individuals who declared to be illiterate or were judged by the interviewer as having questionable capacity to understand the form.

Demographic and Clinical Data

All participants were interviewed for demographic information, including age, gender, educational attainment (highest grade completed), race (white or non-white), and lifetime occupation (predominantly manual or non-manual). Individuals were further classified as married (including cohabiting) or unmarried (never married, divorced or widowed). Economic status was determined according to the Brazilian

Economic Classification Criterion,[~~15~~18] which provides a discrete scale calculated by assigning scores to the number of household assets.

Duration of diabetes was registered and treatment was characterized as oral agents alone or an insulin-containing regimen. Participants were further asked if they had supervision or help taking medications and classified as receiving assistance or not. Because some studies have reported depression as an important factor influencing glycemic control,[~~16~~19] we assessed depressive symptoms using the 15-Item Geriatric Depression Scale (GDS-15).[~~17~~20,~~18~~21]

Functional Health Literacy

We assessed functional health literacy by using the 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18), a test which evaluates pronunciation and comprehension of commonly used medical terms. The SAHLPA-18 has been previously validated in a sample of Brazilian older adults, presenting moderate to high correlations with construct criteria, high internal consistency, and adequate test-retest reliability.[~~19~~22]

We used laminated flash cards, each with a medical term printed in boldface on the top and two association words at the bottom. One of the words is meaningfully associated with the medical term and the other is not. Respondents were shown flash cards one at a time and asked to read aloud the medical term in boldface. The interviewer then read the two association words and asked which one was meaningfully associated with the medical term. Because the purpose of the association questions was to assess comprehension, respondents were instructed not to guess and say "don't know" if they did not know the correct association. The answer was deemed correct only when the respondent correctly pronounced the medical term and made the correct association. One point was scored for each correct item with a maximum score of 18. Using previously validated criteria,~~19~~22 we categorized patients as having inadequate functional health literacy if the SAHLPA-18 score was 1 to 14 and adequate functional health literacy if it was 15 to 18. Patients were considered illiterates if the SAHLPA-18 score was 0 or if individuals did not attempt to complete the test alleging being unable to read at all.

Diabetes Knowledge

Diabetes knowledge was assessed with the Spoken Knowledge in Low Literacy patients with Diabetes (SKILLD), a 10-item test with questions about behaviors patients should have to best manage their diabetes.~~20~~23 The SKILLD is verbally administrated – questions are read aloud in an open-ended format and answers are recorded as either correct ~~of~~ or incorrect. Full marks are given only for complete answers and all the questions are weighted equally. The SKILLD was chosen because it provides measures of diabetes knowledge that are more independent of literacy status, as it does not require reading tasks and the patients are allowed to explain answers with their own words.

Diabetes Outcomes

The most recent HbA1c value extracted from the electronic medical record was used as a measure of glycemic control, reflecting the mean glycaemia over the preceding two to three months. Recently published guidelines from the American Geriatrics Society Expert Panel on the Care of Older Adults with Diabetes Mellitus recommend that the "target goal for HbA1c in older adults generally should be 7.5 to 8.0%".[16] Accordingly, ~~I~~inadequate glycemic control was defined as HbA1c ~~≥ 7~~> 8%. ~~For investigating the association of health literacy with even poorer levels glycemic control, the cutoffs ≥ 8% and ≥ 9% were adopted alternatively. The presence of~~Data on diabetes complications (i.e., retinopathy, nephropathy, and neuropathy) were obtained from the medical records and registered as dichotomous variables (present or absent).

Statistical Analysis

We performed descriptive statistics to characterize the sample and the studied variables. Patients were classified according to their functional health literacy status in one of three ~~ordered~~ categories: illiteracy, inadequate functional health literacy, or adequate functional health literacy. ~~Demographic v~~Variables were compared between the three groups using the Fisher exact test for categorical data, one-way analyses of variance (ANOVA) for continuous ~~or discrete~~ parametric data, and Kruskal-Wallis for continuous non-parametric data. Post hoc tests for determining differences between means were accomplished with the Tukey's honestly significant difference procedure. Effect sizes were calculated using Cohen's d method.

Regression analyses were used to ~~measure~~ explore the association between functional health literacy and glycemic control while controlling for other potentially confounding variables. In primary analyses, functional health literacy and glycemic control were used as continuous variables in hierarchical multiple linear regressions. In these models HbA1c was the dependent variable and the SAHLPA-18 was the primary independent variable. Covariates were entered in four sequential steps for examining their incremental validity, as indicated by changes in the coefficient of determination (R^2). In the first step the SAHLPA-18 was entered without covariates. In the second step, seven socio-demographic variables were entered as a block (i.e., age, gender, race, educational attainment, occupation, economic status, and marital status). The incremental role of four clinical variables was examined on the third step (i.e., depressive symptoms, diabetes duration, treatment regimen, and assistance for taking medications). The SKILLD was entered as the last step, because diabetes knowledge represents a further adjustment factor deemed to be interrelated with health literacy and that has not been used as a covariate in many studies. Because SAHLPA-18 does not provide useful measures in illiterates, those individuals were not included in multiple linear models. We decided to use a linear regression model after a visual inspection, but a fractional polynomial regression was also applied to detect a possible nonlinear association.[24] Because regression models have included a substantial number of correlated variables, multicollinearity was assessed using the variance inflation factor (VIF). ~~literacy and glycemic control were taken as categorical variables in logistic regression models. The odds of inadequate glycemic control were calculated separately for patients with illiteracy and inadequate literacy, taking patients with adequate literacy as a reference. We also used logistic regression models to determine the independent effect of health literacy on the risk of diabetes complications.~~

In secondary analyses, functional health literacy and glycemic control were taken as categorical variables in logistic regression models. The odds of inadequate glycemic control were calculated separately for patients with illiteracy and inadequate functional health literacy, taking patients with adequate functional health literacy as a reference. We also used logistic regression models to determine the independent effect of functional health literacy on the risk of diabetes complications. ~~health literacy and glycemic control were used as continuous variables in multiple linear regressions. In these models HbA1c was the dependent variable, SAHLPA-18 was the primary independent variable, and other potentially confounding factors were entered as covariates. We decided to use a linear regression model after a visual inspection, but for detecting a possible nonlinear association a fractional polynomial regression was also applied.[21] Because SAHLPA-18 does not provide useful measures in illiterates, those individuals were not included in multiple linear models. In all regression models,~~

~~controlled variables were age, gender, education, race, economic status, lifetime occupation, marital status, depressive symptoms, diabetes duration, treatment regimen, diabetes knowledge, and assistance for taking medications~~.

Two-way interactions were carried out to investigate whether the impact of functional health literacy on glycemic control differ according to age, gender, depressive symptoms, diabetes duration, insulin use, and assistance for taking medications. In addition, we have investigated interactions in the fully adjusted linear regression model between all the significant variables.

Based on a two-sided significance level of 0.05 and 80% power, we estimated a total sample size of 128 patients for detecting differences between two groups with medium effect sizes (Cohen's d = 0.5). Statistical analyses were performed with Stata version 12.1 (Stata Corp. LP, College Station, TX) and power calculations were conducted with the software G*Power 3.1.5.[~~22~~-25] All statistical tests were two-tailed, and an alpha level of less than 0.05 was used to indicate statistical significance.

RESULTS

Two hundred and twenty-five older adults with type 2 diabetes were screened for participation. Of these, 66 were ineligible because they had dementia (n=51), renal failure (n=9), did not speak fluent Portuguese (n=3), had anemia (n=2), and aphasia (n=1). All remaining 159 patients were approached at a clinical appointment. Of these, 13 were excluded because they were considered frail according to the SOF criteria, 10 presented poor visual acuity, one had severe hearing impairment, and six refused to participate.

Our sample consisted of 129 older adults with a mean age (SD) of 75.9 (~~±~~6.2) years, 69.8% of whom female. Median educational attainment was 4 years, with 14.7%

of the individuals having no formal education and 82.9% having less than a high-school diploma. Functional ~~H~~health literacy below adequate as measured by the SAHLPA-18 was encountered in 56.6% of the sample – 11.6% who were illiterate and 45.0% who presented inadequate functional health literacy. Overall, the median duration since the diagnosis of diabetes was 10 years, 31.8% of the patients were taking insulin, and the mean (SD) HbA1c was 7.2% (~~±~~1.4). Based on the most recent results for HbA1c, ~~50.4~~52.7% of the patients were in tight control (HbA1c ≤~~<~~7%), ~~27.1~~24.8% were in fair control (HbA1c 7.1-~~7.9~~8%), and ~~10.9~~22.5% ~~were in poor~~presented inadequate glycemic control (HbA1c >8-~~8.9~~%)~~ and 11.6% were in very poor control (HbA1c ≥9%)~~. Table 1 lists additional demographic and clinical characteristics of the sample.

Patients with lower functional health literacy levels were more likely to have a non-white ethnicity, present lower ~~scores on the~~ economic status ~~scale~~, have a manual occupation, report lower educational attainment, and have less diabetes-specific knowledge. Overall, one-way ANOVA detected a significant difference in HbA1c means across functional health literacy levels (p=0.034). Post hoc tests revealed a significant difference between individuals with adequate and inadequate ~~and adequate~~ functional health literacy (HbA1c ~~7.6~~6.96 *vs* ~~7.0~~7.56; p=0.049), with a Cohen's d of 0.44 indicating a medium effect size.[26] There was no difference in glycemic control~~but not~~ between individuals with adequate functional health literacy and those who were considered illiterates ~~and those with adequate literacy~~ (HbA1c ~~6.8~~6.96 *vs* ~~7.0~~6.85; p=0.953).

In linear regression models, lower SAHLPA-18 scores were associated with higher levels of HbA1c throughout all adjustment steps. In the fully adjusted model, the SAHLPA-18 was the variable more strongly associated with glycemic control, with a standardized beta of -0.42 (p<0.001). This means that, with all other variables held constant, a one SD increase on the SAHLPA-18 would be associated with an improvement of 0.42 SD (0.6%) on the predicted HbA1c. The other variables associated with a poorer glycemic control in the fully adjusted model were lack of assistance for taking medications, and longer diabetes duration (Table 2). The maximum VIF was 2.11 and mean VIF was 1.46, indicating that multicollinearity was not a problem. Comparison of model fitness parameters showed that a linear regression performed as well as a second-order fractional polynomial regression (*P*=0.986), indicating that the relationship between SAHLPA-18 and HbA1c can be assumed to be linear in this sample. Interaction analyses did no yield any significant effects.

~~After adjustment for potentially confounding variables~~In fully adjusted logistic regression models, patients with inadequate functional health literacy were more likely than patients with adequate functional health literacy to present ~~poor and very poor~~ inadequate glycemic control (HbA1c >8%), with adjusted ~~OR =~~odds ratio of 4.76 (95% ~~I~~ CI 1.36-16.63). ~~for HbA1c ≥ 8% and adjusted OR = 9.19 (95% IC 1.57-53.77) for HbA1c ≥ 9%~~. ~~The association between inadequate health literacy and HbA1c ≥ 7% did not reach statistical significance. Likewise, w~~We did not find significant associations between inadequate functional health literacy ~~status~~ and diabetes complications. In all adjusted models, illiterate individuals did not have poorer diabetes outcomes when compared with individuals with adequate functional health literacy (Table ~~2~~3).

~~In a linear model with adjustment for confounding variables, higher levels of HbA1c were associated with lower scores on SAHLPA-18 score, lack of assistance for taking medications, and longer diabetes duration. In that model, for each one-point decrement in SAHLPA-18 score, the HbA1c increased by approximately 0.2 (Table 3). The maximum VIF was 2.1, indicating that multicollinearity was not a problem. Comparison of model fitness parameters showed that a linear regression performed as~~

~~well as a second-order fractional polynomial regression (P=0.986 for comparison of deviance between both models), indicating that the relationship between SAHLPA-18 and HbA1c can be assumed to be linear in this sample.~~

DISCUSSION

~~Our study demonstrates that, i~~In a sample of low-educated older patients with type 2 diabetes, our study demonstrates that lower scores on a functional health literacy test are associated with a higher likelihood of poor glycemic control after adjusting for potential confounders. ~~Associations were stronger with higher cut-offs for defining inadequate glycemic control, suggesting that better levels of health literacy are more useful for protecting individuals from poor and very poor control than for achieving optimal targets.~~ Our result is consistent with that reported by Tang et al.,[~~7~~10] who studied a sample of Chinese patients with educational levels that are compatible with those encountered in our sample.

It has been suggested that there may be a threshold for the association between health literacy and health outcomes, i.e., a certain level of health literacy is needed for a good outcome, but higher levels add little benefit.[~~23~~27] According to that rationale, the influence of health literacy on health outcomes would be stronger at the lower end of the health literacy spectrum, with the association curve tending to reach a plateau at the higher end. Our study, as well as that of Tang et al.,[10] has included a sample which represents properly the lowest levels of the health literacy spectrum, where the association of health literacy with health outcomes is deemed to be stronger. This may explain, at least in part, the convincing associations that have been found in both studies, but ~~M~~more studies with very low educated populations ~~of~~from developing countries are needed to confirm that hypothesis.

In addition to the preceding hypothesis, two additional factors can be invoked to explain the ~~relatively strong~~ significant association observed in our study between functional health literacy and glycemic control. First, we have made a careful selection of the sample, excluding conditions that can influence scores in functional health literacy tests, affect the accuracy of the HbA1c assay, or determine different targets of glycemic control. Second, the study was conducted in a government-financed health system which provides medications at no cost. This factor may attenuate inequalities in access to therapeutic resources, making the role of functional health literacy more evident.

After conducting a systematic review, Al Sayah et al. suggested that a confounder could explain the inconsistency in results across studies designed to investigate the effects of health literacy on diabetes outcomes.[69] Significant associations between functional health literacy and HbA1c were found only in studies that did not adjust for diabetes knowledge. Our study brings a new piece of evidence that is contrary to that hypothesis – we have controlled for diabetes knowledge and still have found a significant association between functional health literacy and glycemic control. The use of a verbally administered test to evaluate diabetes knowledge in our study may explain this contrasting result. In prior studies, tests of diabetes knowledge which involve reading and writing ~~tasks~~ may have provided measures that are highly correlated with ~~those of~~ functional health literacy tests, thus ~~adding multicollinearity to the regression models~~suppressing some of the effects of this variable.[24]

In our study the diabetes knowledge test was only moderately correlated with the measure of functional health literacy (r=0.39) and its corresponding VIF was 1.70, indicating that it did not cause multicollinearity. When the SKILLD was added to a model already containing the SAHLPA-18, demographic characteristics, and clinical factors, it was not significantly associated with functional health literacy, it did not change the results, and did not improve predictive power of the regression model (Table 2). Findings from a recent study conducted by Jeppesen et al. have raised concerns about the properties of the SKILLD.[28] Besides presenting only a moderate correlation with a measure of criterion validity, the test has been shown to have limited inter-rater reliability and low internal consistence. Taking in account the findings of Jeppesen et al. and those of the present study, it is worthy to suggest that the properties of the SKILLD should be carefully investigated in future studies before it can be assumed to provide valid and useful measures.

Contrary to our expectations, illiterate patients did not have poorer glycemic control when compared to patients with adequate functional health literacy. This finding raises questions on how illiterate patients may compensate for their difficulties. We can speculate that, when caring for patients who report being unable to read at all, health professionals and family members are more aware of the need for compensation strategies. In contrast, among individuals who report being able to read, ~~limited~~ inadequate health literacy is a frequently unrecognized condition.[~~25~~5] Unfortunately, our study did not include a specific instrument~~s~~ to assess social support, what would have allowed us to explore ~~the~~a possible interaction of this factor with functional health literacy ~~with social support and self-efficacy~~ in determining diabetes outcomes. In future studies ~~such measures~~instruments designed to assess social support may possibly ~~would better~~ explain how illiterate patients can compensate for their difficulties.

In an Iranian diabetes clinic, Jahanlou and Karami did not find a significant difference in HbA1c levels between illiterate (n=108) and literate (n=148) patients.[29] Similarly, Hawthorne and Tomlinson reported comparable levels of HbA1c between illiterate (n=54) and literate (n=158) Pakistani patients with type 2 diabetes.[30] However, both studies have based their reports on bivariate analyses, without appropriate control for confounding variables. In our study, the relatively small subsample of illiterate patients provided limited power to reject differences with small or even moderate magnitude. Therefore, these preliminary findings regarding glycemic control in illiterate patients should be confirmed in future studies with adequate sample size and adjustment for confounding variables.

~~Because the subgroup of illiterate patients was relatively small, we cannot rule out a modest difference in HbA1c levels between patients with illiteracy and adequate literacy. In a post-hoc analysis with power set at 0.80 and alpha 0.05, we calculated that our sample would be adequate to detect an effect size of 0.83, corresponding to a difference of 0.9% in mean HbA1c levels.~~

Our study has a number of limitations. First, its cross-sectional design does not allow the establishment of causal associations between inadequate functional health literacy and poor diabetes outcomes. Second, although we have excluded individuals with a diagnosis of dementia, we did not screen~~ed~~ for dementia and did not make adjustments for cognitive performance. Third, our study was clearly underpowered to investigate the association between functional health literacy and diabetes complications, which presented low prevalence in our sample, varying from 11.6% (neuropathy) to 13.2% (nephropathy). Fourth, although the SAHLPA-18 has been shown to be valid and present good psychometric properties in Brazilian older adults,[22] it does not include tasks to assess some important aspects of health literacy, such as numeracy skills, interactive skills, and critical skills.[31]

In conclusion, this study found that, in a sample of low-educated older patients with type 2 diabetes, lower functional health literacy skills were associated with higher odds of poor glycemic control. ~~Contrary to our expectations, illiterate patients did not~~

~~present poorer diabetes outcomes, raising the hypothesis that these individuals are more likely to have their difficulties recognized and compensated.~~ These findings reinforce ~~that compensation strategies may be effective and highlight~~ the importance of identifying limited functional health literacy in clinical practice.

CONTRIBUTORS

JGS participated in study design, collected data, and wrote the first draft of the manuscript. DA conceived the study, conducted statistical analysis, and wrote the final draft of the manuscript. RMM, ALB, FC, and WJF participated in study design and revised the manuscript.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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Table 1. Characteristics of the sample stratified by functional health literacy level

	Functional Health Literacy Level				
Characteristics	Total (n=129)	Illiterate (n=15)	Inadequate (n=58)	Adequate (n=56)	*P*-value*
Age, mean (SD), y	75.9 (6.2)	78.2 (6.3)	75.9 (5.9)	75.3 (6.4)	0.280
Female gender, No. (%)	90 (69.8)	14 (93.3)	37 (63.8)	39 (69.6)	0.074
White race, No. (%)	61 (47.9)	4 (26.7)	21 (36.2)	36 (64.3)	0.003
Education, median (IQR), y	4 (2-8)	0 (0-0)	4 (3-4)	7.5 (4-11)	<0.001
Economic level (BECC score), mean (SD)	19.9 (6.2)	16.4 (5.8)	19.2 (5.5)	21.7 (6.5)	0.006
Manual occupation, No. (%)	67 (51.9)	14 (93.3)	30 (51.7)	23 (41.1)	0.001
Married, No. (%)	42 (32.6)	1 (6.7)	19 (32.8)	22 (39.3)	0.057
Assistance with medications, No. (%)	22 (17.1)	5 (33.3)	10 (17.2)	7 (12.5)	0.200
Diabetes knowledge (SKILLD), mean (SD)	4.2 (2.6)	2.5 (2.6)	3.5 (2.2)	5.3 (2.6)	< 0.001
Health literacy (SAHLPA-18), median (IQR)	13 (10-16)	0 (0-0)	11.5 (10-13)	16 (15-17)	< 0.001
Depressive symptoms (GDS-15), median (IQR)	3 (1-5)	4 (2.3-5.8)	3 (1-5)	2 (1-4.5)	0.170
Insulin containing regimen, No. (%)	41 (31.8)	6 (40.0)	18 (31.0)	17 (30.4)	0.772
Diabetes duration, median (IQR), y	10 (5-20)	20 (7.3-20)	10 (5-19)	12 (4.5-20)	0.365
HbA1C, mean (SD)	7.2 (1.4)	6.8 (1.1)	7.6 (1.6)	7.0 (1.1)	0.034
LDL cholesterol, mean (SD)	110.5 (36.5)	105.7 (29.6)	108.3 (38.5)	114.1 (36.3)	0.605
Systolic Blood Pressure, mean (SD)	143.1 (23.5)	147.3 (23.8)	142.9 (23.7)	142.0 (23.6)	0.741
Diastolic Blood Pressure, mean (SD)	79.4 (10.8)	78.0 (12.1)	79.7 (7.9)	79.5 (13.1)	0.866
Any microvascular complication, No. (%)	33 (25.6)	3 (20.0)	18 (31.0)	12 (21.4)	0.468
Retinopathy, No. (%)	16 (12.4)	0 (0)	10 (17.2)	6 (10.7)	0.210
Nephropathy, No. (%)	17 (13.2)	1 (6.7)	9 (15.5)	7 (12.5)	0.813
Neuropathy, No. (%)	15 (11.6)	3 (20.0)	6 (10.3)	6 (10.7)	0.538
Any macrovascular complication, No. (%)	37 (28.7)	5 (33.3)	20 (34.5)	12 (21.4)	0.262
Cerebrovascular disease, No. (%)	15 (11.6)	0 (0)	10 (17.2)	5 (8.9)	0.142
Coronary artery disease, No. (%)	17 (13.2)	4 (26.7)	9 (15.5)	4 (7.1)	0.092
Peripheral artery disease, No. (%)	11 (8.5)	2 (13.3)	6 (10.3)	3 (5.4)	0.451

*The Fisher exact test was used for categorical variables, analysis of variance for means of continuous variables, and Kruskal-Wallis test for medians of continuous variables.
Abbreviations: standard deviation (SD); interquartile range (IQR); Brazilian Economic Classification Criterion (BECC); Spoken Knowledge in Low Literacy patients with Diabetes (SKILLD); 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18); 15-Item Geriatric Depression Scale (GDS-15); Hemoglobin A1c (HbA1c); Low Density Lipoprotein (LDL).

Table 2. Association between HbA1c and patient characteristics in hierarchical multiple linear regression models (n=114)

	Standardized beta coefficients			
Independent Variables	**Step 1** *R^2=0.06*	**Step 2** *R^2=0.15*	**Step 3** *R^2=0.29*	**Step 4** *R^2=0.29*
Health literacy, SAHLPA-18 score	-0.25**	-0.31**	-0.41***	-0.42***
Age (years)		-0.16	-0.16	-0.16
Gender (female *vs* male)		0.08	0.16	0.16
Race (white *vs* nonwhite)		0.03	0.03	0.03
Education (years)		0.11	0.12	0.10
Occupation (manual *vs* non-manual)		0.14	0.11	0.10
Economic status (BECC score)		0.16	0.15	0.15
Marital status (married *vs* unmarried)		-0.09	-0.08	-0.08
Depressive symptoms, GDS-15 score			-0.07	-0.06
Diabetes duration (years)			0.25**	0.24*
Insulin containing regimen (yes *vs* no)			0.17	0.16
Assistance with medications (yes *vs* no)			-0.22*	-0.23*
Diabetes knowledge, SKILLD score				0.05

Multiple linear regression models with HbA1c as the dependent variable, SAHLPA-18 as the primary independent variable, and other characteristics as covariates. The coefficient of determination (R^2) indicates the proportion of the variance of the HbA1c which can be explained by the set of predictors.

Abbreviations: 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18); Brazilian Economic Classification Criterion (BECC); 15-Item Geriatric Depression Scale (GDS-15); Spoken Knowledge in Low Literacy patients with Diabetes (SKILLD).

*P<0.05

**p<0.01

***p<0.001

Table ~~2~~3. Functional ~~H~~health literacy ~~level~~ and poor diabetes outcomes (n=129)

Outcome	Health Literacy Level	No. (%)	Odds Ratio (95% Confidence Interval)	
			Unadjusted	Adjusted*
~~HbA1C ≥ 7%~~	~~Adequate~~	~~27 (48.2)~~	~~1.00~~	~~1.00~~
	~~Inadequate~~	~~33 (56.9)~~	~~1.42 (0.68-2.97)~~	~~2.33 (0.83-6.59)~~
	~~Illiteracy~~	~~4 (26.7)~~	~~0.39 (0.11-1.38)~~	~~0.38 (0.06-2.28)~~
Inadequate Glycemic Control (HbA1C ~~≥~~≥ 8%)	Adequate	9 (16.1)	1.00	1.00
	Inadequate	18 (31.0)	2.35 (0.95-5.81)	4.76 (1.36-16.63)
	Illiteracy	2 (13.3)	0.80 (0.15-4.19)	1.17 (0.13-10.87)
~~HbA1C ≥ 9%~~	~~Adequate~~	~~3 (5.4)~~	~~1.00~~	~~1.00~~
	~~Inadequate~~	~~11 (19.0)~~	~~4.13 (1.09-15.72)~~	~~9.19 (1.57-53.77)~~
	~~Illiteracy~~	~~1 (6.7)~~	~~1.26 (0.12-13.08)~~	~~2.15 (0.11-42.64)~~
Retinopathy	Adequate	6 (10.7)	1.00	1.00
	Inadequate	10 (17.2)	1.74 (0.59-5.15)	2.88 (0.60-13.86)
	Illiteracy	0 (0.0)	NA	NA
Nephropathy	Adequate	7 (12.5)	1.00	1.00
	Inadequate	9 (15.5)	1.29 (0.44-3.73)	0.91 (0.19-4.42)
	Illiteracy	1 (6.7)	0.50 (0.06-4.41)	0.23 (0.01-3.85)
Neuropathy	Adequate	6 (10.7)	1.00	1.00
	Inadequate	6 (10.3)	0.96 (0.29-3.18)	0.98 (0.22-4.36)
	Illiteracy	3 (20.0)	2.08 (0.45-9.55)	1.24 (0.15-10.27)

*Adjusted for: age, gender, race, educational attainment, ~~race,~~ occupation, economic status, ~~lifetime occupation,~~ marital status, assistance for taking medications, depressive symptoms, diabetes duration, treatment regimen, and diabetes knowledge~~, and assistance for taking medications~~.
Abbreviation~~s~~: not applicable (NA)

~~**Table 3.** Association between patients characteristics and HbA1c in a linear multivariate model (n=114)~~

	~~Unadjusted~~		~~Adjusted*~~	
~~Predictor~~	~~Coefficient~~	~~*P* Value~~	~~Coefficient~~	~~*P* Value~~
~~Health literacy, SAHLPA-18 score (0-18)~~	~~-0.1099~~	~~0.0075~~	~~-0.1857~~	~~0.0002~~
~~Age (years)~~	~~-0.0306~~	~~0.1562~~	~~-0.0361~~	~~0.1294~~
~~Gender (female *vs* male)~~	~~0.3013~~	~~0.2785~~	~~0.4764~~	~~0.1293~~
~~Education (years)~~	~~-0.0161~~	~~0.6077~~	~~0.0346~~	~~0.3990~~
~~Economic level, BECC score (0-34)~~	~~0.0253~~	~~0.2426~~	~~0.0338~~	~~0.1178~~
~~Race (white *vs* nonwhite)~~	~~0.3965~~	~~0.1295~~	~~-0.0864~~	~~0.7544~~
~~Lifetime occupation (manual *vs* nonmanual)~~	~~0.3444~~	~~0.1895~~	~~0.2773~~	~~0.3606~~
~~Marital status (married *vs* unmarried)~~	~~-0.2984~~	~~0.2747~~	~~-0.2364~~	~~0.4098~~
~~Depressive symptoms, GDS-15 score (0-15)~~	~~0.0214~~	~~0.6669~~	~~-0.0304~~	~~0.5366~~
~~Diabetes duration (years)~~	~~0.0335~~	~~0.0187~~	~~0.0371~~	~~0.0123~~
~~Insulin containing regimen (yes vs no)~~	~~0.6294~~	~~0.0255~~	~~0.4817~~	~~0.1041~~
~~Assistance with medications (yes vs no)~~	~~-0.5692~~	~~0.1209~~	~~-0.8753~~	~~0.0143~~
~~Diabetes knowledge, SKILLD score (0-10)~~	~~0.0485~~	~~0.3481~~	~~0.0252~~	~~0.6772~~

~~Multiple linear regression models with HbA1c as a dependent variable, SAHLPA-18 as the primary independent variable.~~

~~* Adjusted for age, gender, educational attainment, race, economic status, lifetime occupation, marital status, depressive symptoms, diabetes duration, treatment regimen, diabetes knowledge, and assistance for taking medications.~~

~~Abbreviations: 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18); Brazilian Economic Classification Criterion (BECC); 15-Item Geriatric Depression Scale (GDS-15); Spoken Knowledge in Low Literacy patients with Diabetes (SKILLD).~~

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1OK	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2 OK	Explain the scientific background and rationale for the investigation being reported
Objectives	3 OK	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4 OK	Present key elements of study design early in the paper
Setting	5 OK	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6 OK	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls OK *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7 OK	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8 OK	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9 OK	Describe any efforts to address potential sources of bias
Study size	10 OK	Explain how the study size was arrived at
Quantitative variables	11 OK	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12 OK	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	13 OK	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14 OK	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15 OK	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		OK *Cross-sectional study*—Report numbers of outcome events or summary measures
Main results	16 OK	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17 OK	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18 OK	Summarise key results with reference to study objectives
Limitations	19 OK	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20 OK	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21 OK	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22 OK	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Functional health literacy and glycemic control in older adults with type 2 diabetes: a cross-sectional study

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Complete List of Authors:	Souza, Jonas; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine Apolinario, Daniel; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine Magaldi, Regina; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine Busse, Alexandre; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine Campora, Flavia; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine Jacob-Filho, ; Wilson; University of São Paulo Medical School, Geriatrics Division, Department of Internal Medicine

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TITLE:

Functional health literacy and glycemic control in older adults with type 2 diabetes: a cross-sectional study

Jonas Gordilho Souza[a], MD; Daniel Apolinario[a*], MD, PhD; Regina Miksian Magaldi[a], MD; Alexandre Leopold Busse[a], MD, PhD; Flavia Campora[a], MD; Wilson Jacob-Filho[a], MD, PhD

[a] Geriatrics Division, Department of Internal Medicine, University of São Paulo Medical School, São Paulo, SP, Brazil

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Health Literacy and Glycemic Control

***CORRESPONDING AUTHOR AT:**

Geriatrics Division, University of São Paulo Medical School, Av. Dr. Enéas de Carvalho Aguiar, 155, 8º Andar, Bloco 8, São Paulo, SP, CEP 05403-900, Brazil. Tel.: +55-11-30696236

E-mail address: daniel.apolinario@usp.br

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Health Literacy; Diabetes; Glycemic Control; Older Adults

ABSTRACT

OBJECTIVES: To investigate the relationship between functional health literacy and glycemic control in a sample of older patients with type 2 diabetes.

DESIGN: Cross-sectional study.

SETTING: A government-financed outpatient geriatric clinic in São Paulo, Brazil.

PARTICIPANTS: 129 older patients with type 2 diabetes, mean (SD) age of 75.9 (6.2) years, mean HbA1c of 7.2% (1.4), of which 14.7% had no formal education and 82.9% had less than a high-school diploma.

MEASURES: HbA1c was used as a measure of glycemic control. Functional health literacy was assessed with the 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18), a validated instrument to evaluate pronunciation and comprehension of commonly used medical terms. Regression models were controlled for demographic data, depressive symptoms, diabetes duration, treatment regimen, diabetes knowledge, and assistance for taking medications.

RESULTS: Functional health literacy below adequate was encountered in 56.6% of the sample. After controlling for potential confounding factors, patients with inadequate functional health literacy were more likely than patients with adequate functional health literacy to present poor glycemic control (OR=4.76; 95% CI 1.36-16.63). In a fully adjusted linear regression model, lower functional health literacy (β=-0.42; $p<0.001$), longer diabetes duration (β=0.24; p=0.012), and lack of assistance for taking medications (β=0.23; p=0.014) were associated with higher levels of HbA1c. Contrary to our expectations, illiterate patients did not have poorer outcomes when compared to patients with adequate functional health literacy, raising the hypothesis that illiterate individuals are more likely to have their difficulties recognized and compensated. However, the small subsample of illiterate patients provided limited power to reject differences with small magnitude.

CONCLUSION: Patients with inadequate functional health literacy presented higher odds of poor glycemic control. These findings reinforce the importance of addressing limited functional health literacy in clinical practice.

ARTICLE SUMMARY

Article focus

• Although many theoretical mechanisms are proposed that link health literacy to diabetes outcomes, the direct association between functional health literacy and glycemic control is still controversial.

• In particular, there is paucity of data on the adequacy of glycemic control in patients who are illiterate and in those who have only the most rudimentary levels of literacy.

Key messages

• Older patients with inadequate functional health literacy were more likely to present poor glycemic control when compared to patients with adequate functional health literacy, but illiterate patients did not present a higher risk of poor glycemic control.

• We hypothesize that individuals who report being unable to read are more likely to have their difficulties recognized and compensated. In contrast, among individuals who report being able to read, limited functional health literacy is frequently unrecognized and less likely to be compensated.

Strengths and limitations of this study

• A wide range of potentially confounding variables has been controlled, including depression, diabetes duration, treatment regimen, diabetes knowledge, and assistance for taking medications.

• The relatively small subsample of illiterate patients provided limited power to reject risk differences with small magnitude. Thus, these preliminary findings should be confirmed in further studies.

INTRODUCTION

Health literacy has been defined by the World Health Organization as " the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand and use information in ways which promote and maintain good health".[1] The concept of health literacy is not restricted to the ability to read and follow medical instructions. It includes a range of communicative and critical skills such as searching for specific health knowledge, evaluating information for credibility, balancing risks and benefits, expressing needs, and negotiating preferences.

The term "functional health literacy" has been used to imply one's ability to function adequately in health care settings, as determined by instruments which access basic skills needed to deal with health-related written materials.[2] This somewhat narrow approach misses the richness implied by the WHO definition, but warrants practical feasibility for studies investigating the relationships between health literacy and health outcomes. Inadequate functional health literacy has been independently associated with poorer ability to take medications appropriately, lower utilization of preventive services, more hospitalizations, poorer overall health status, and higher mortality rates.[3] Multiple interventions exist to lessen the negative effects of inadequate functional health literacy,[4] but health professionals often overestimate patients' abilities and fail to recognize the problem.[5]

Some segments of the population are at greater risk for inadequate health literacy, including the socioeconomically disadvantaged, immigrants, and older adults. In a study that included Medicare enrollees aged 65 years and older, functional health literacy skills declined dramatically with age, even after adjusting for educational status and cognitive impairment.[6] Inadequate health literacy may disproportionately affect the health of older persons, not only because it is more prevalent in this age group, but also

because older persons are more exposed to health care services and more likely to receive complex therapeutic regimens.[7]

Diabetes care involves extensive self-management behaviors and requires pharmacological regimens that tend to become increasingly complex over time. This prototypical chronic disease constitutes a representative model for studying the influence of health literacy on health outcomes. However, although many theoretical mechanisms are proposed that link health literacy to diabetes self-care and clinical outcomes, the direct association between functional health literacy and glycemic control is still controversial.[8]

In a recent systematic review, 13 studies were included that have explored the relationship between health literacy and glycemic control.[9] Results were inconsistent across studies, and the heterogeneity did not allow the estimation of an overall effect. Therefore, the evidence for direct association was rated insufficient. These findings may indicate that health literacy is related to certain outcomes in particular populations, but not in others. Only one study was conducted in a developing country, including a population with a very low levels educational attainment.[10] In that study, higher scores on the Short Test of Functional Health Literacy in Adults (S-TOFHLA) were strongly associated with reduced levels of glycosylated hemoglobin. In general, there is paucity of data on the association between health literacy and glycemic control in patients who have only rudimentary reading skills and in those who are unable to read at all.

The purpose of this study was to determine the independent association of functional health literacy with glycemic control in a Brazilian sample of heterogeneous, predominantly low-educated older adults with type 2 diabetes.

METHODS

Subjects

A convenient sample was recruited between June 2011 and July 2012 from a government-financed outpatient geriatric clinic in the city of São Paulo, southeastern Brazil. During this period, 225 older adults with type 2 diabetes were screened for participation. At the time of the study, there was no diabetes management program or educational intervention in place. All patients were treated by geriatricians or geriatricians in training, were provided diabetes medications at no cost, and had access to the same range of services.

Research staff reviewed medical records and spoke with patients to verify inclusion and exclusion criteria. Eligibility criteria included: (1) age ≥ 60 years; (2) self-reported ability to speak fluent Portuguese; (3) type 2 diabetes currently being treated with daily medication; and (4) a glycosylated hemoglobin (HbA1c) measurement performed within a 6 month period. Patients were ineligible if they had a hearing, vision, motor or speech problem that precluded adequate interaction with the interviewer or impeded appropriate completion of the proposed assessments. Patients with a diagnosis of dementia were excluded because cognitive impairment has been associated with poor performance in functional health literacy tests and may affect an individual's ability to manage drug regimens.[11,12] Patients with overt thyroid dysfunction (thyroid-stimulating hormone < 0.1 or > 10mU/L), anemia (hemoglobin < 11 mg/dL for men and < 10 mg/dL for women), and severe renal failure (estimated glomerular filtration rate < 30ml/min/1.73m^2) were excluded because these conditions can affect the accuracy of the HbA1c assay.[13-15]

We further excluded subjects who fulfilled criteria for frailty, because less stringent targets of glycemic control have been proposed for frail elderly.[16] Frailty status

was determined according to the Study of Osteoporotic Fracture (SOF) index.[17] The SOF index is composed of following three items: (1) weight loss of more than 5% during the last year; (2) inability to rise from a chair five consecutive times without using the arms; and (3) self-perceived reduced energy level. Subjects were assessed systematically and excluded if at least two of the three criteria were fulfilled.

The research protocol was approved by the local ethics committee. Eligible patients attending to scheduled appointments were approached in the clinic waiting room and provided a description of the study procedures. An informed consent was obtained before the interview. The consent form was read aloud and explained in plain language for those individuals who declared to be illiterate or were judged by the interviewer as having questionable capacity to understand the form.

Demographic and Clinical Data

All participants were interviewed for demographic information, including age, gender, educational attainment (highest grade completed), race (white or non-white), and lifetime occupation (predominantly manual or non-manual). Individuals were further classified as married (including cohabiting) or unmarried (never married, divorced or widowed). Economic status was determined according to the Brazilian Economic Classification Criterion,[18] which provides a discrete scale calculated by assigning scores to the number of household assets.

Duration of diabetes was registered and treatment was characterized as oral agents alone or an insulin-containing regimen. Participants were further asked if they had supervision or help taking medications and classified as receiving assistance or not. Because some studies have reported depression as an important factor influencing glycemic control,[19] we assessed depressive symptoms using the 15-Item Geriatric Depression Scale (GDS-15).[20,21]

Functional Health Literacy

We assessed functional health literacy by using the 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18), a test which evaluates pronunciation and comprehension of commonly used medical terms. The SAHLPA-18 has been previously validated in a sample of Brazilian older adults, presenting moderate to high correlations with construct criteria, high internal consistency, and adequate test-retest reliability.[22]

We used laminated flash cards, each with a medical term printed in boldface on the top and two association words at the bottom. One of the words is meaningfully associated with the medical term and the other is not. Respondents were shown flash cards one at a time and asked to read aloud the medical term in boldface. The interviewer then read the two association words and asked which one was meaningfully associated with the medical term. Because the purpose of the association questions was to assess comprehension, respondents were instructed not to guess and say "don't know" if they did not know the correct association. The answer was deemed correct only when the respondent correctly pronounced the medical term and made the correct association. One point was scored for each correct item with a maximum score of 18. Using previously validated criteria,[22] we categorized patients as having inadequate functional health literacy if the SAHLPA-18 score was 1 to 14 and adequate functional health literacy if it was 15 to 18. Patients were considered illiterates if the SAHLPA-18 score was 0 or if individuals did not attempt to complete the test alleging being unable to read at all.

Diabetes Knowledge

Diabetes knowledge was assessed with the Spoken Knowledge in Low

Literacy patients with Diabetes (SKILLD), a 10-item test with questions about behaviors patients should have to best manage their diabetes.[23] The SKILLD is verbally administrated – questions are read aloud in an open-ended format and answers are recorded as either correct or incorrect. Full marks are given only for complete answers and all the questions are weighted equally. The SKILLD was chosen because it provides measures of diabetes knowledge that are more independent of literacy status, as it does not require reading tasks and the patients are allowed to explain answers with their own words.

Diabetes Outcomes

The most recent HbA1c value extracted from the electronic medical record was used as a measure of glycemic control, reflecting the mean glycaemia over the preceding two to three months. Recently published guidelines from the American Geriatrics Society Expert Panel on the Care of Older Adults with Diabetes Mellitus recommend that the "target goal for HbA1c in older adults generally should be 7.5 to 8.0%".[16] Accordingly, inadequate glycemic control was defined as HbA1c > 8%. Data on diabetes complications (i.e., retinopathy, nephropathy, and neuropathy) were obtained from the medical records and registered as dichotomous variables (present or absent).

Statistical Analysis

We performed descriptive statistics to characterize the sample and the studied variables. Patients were classified according to their functional health literacy status in one of three categories: illiteracy, inadequate functional health literacy, or adequate functional health literacy. Variables were compared between the three groups using the Fisher exact test for categorical data, one-way analyses of variance (ANOVA) for continuous parametric data, and Kruskal-Wallis for continuous non-parametric data.

Post hoc tests for determining differences between means were accomplished with the Tukey's honestly significant difference procedure. Effect sizes were calculated using Cohen's d method.

Regression analyses were used to explore the association between functional health literacy and glycemic control while controlling for other potentially confounding variables. In primary analyses, functional health literacy and glycemic control were used as continuous variables in hierarchical multiple linear regressions. In these models HbA1c was the dependent variable and the SAHLPA-18 was the primary independent variable. Covariates were entered in four sequential steps for examining their incremental validity, as indicated by changes in the coefficient of determination (R^2). In the first step the SAHLPA-18 was entered without covariates. In the second step, seven socio-demographic variables were entered as a block (i.e., age, gender, race, educational attainment, occupation, economic status, and marital status). The incremental role of four clinical variables was examined on the third step (i.e., depressive symptoms, diabetes duration, treatment regimen, and assistance for taking medications). The SKILLD was entered as the last step, because diabetes knowledge represents a further adjustment factor deemed to be interrelated with health literacy and that has not been used as a covariate in many studies. Because SAHLPA-18 does not provide useful measures in illiterates, those individuals were not included in multiple linear models. Because regression models have included a substantial number of correlated variables, multicollinearity was assessed using the variance inflation factor (VIF).

In secondary analyses, functional health literacy and glycemic control were taken as categorical variables in logistic regression models. The odds of inadequate glycemic control were calculated separately for patients with illiteracy and inadequate health literacy taking patients with adequate functional health literacy as a reference.

We also used logistic regression models to determine the independent effect of health literacy on the risk of diabetes complications.

Two-way interactions were carried out to investigate whether the impact of functional health literacy on glycemic control differ according to age, gender, depressive symptoms, diabetes duration, insulin use, and assistance for taking medications. In addition, we have investigated interactions between all the variables that were significantly associated with glycemic control in the fully adjusted linear regression model.

Based on a two-sided significance level of 0.05 and 80% power, we estimated a total sample size of 128 patients for detecting differences between two groups with medium effect sizes (Cohen's d = 0.5). Statistical analyses were performed with Stata version 12.1 (Stata Corp. LP, College Station, TX) and power calculations were conducted with the software G*Power 3.1.5.[24] All statistical tests were two-tailed, and an alpha level of less than 0.05 was used to indicate statistical significance.

RESULTS

Two hundred and twenty-five older adults with type 2 diabetes were screened for participation. Of these, 66 were ineligible because they had dementia (n=51), renal failure (n=9), did not speak fluent Portuguese (n=3), had anemia (n=2), and aphasia (n=1). All remaining 159 patients were approached at a clinical appointment. Of these, 13 were excluded because they were considered frail according to the SOF criteria, 10 presented poor visual acuity, one had severe hearing impairment, and six refused to participate.

Our sample consisted of 129 older adults with a mean age (SD) of 75.9 (6.2) years, 69.8% of whom female. Median educational attainment was 4 years, with 14.7%

of the individuals having no formal education and 82.9% having less than a high-school diploma. Functional health literacy below adequate as measured by the SAHLPA-18 was encountered in 56.6% of the sample – 11.6% who were illiterate and 45.0% who presented inadequate functional health literacy. Overall, the median duration since the diagnosis of diabetes was 10 years, 31.8% of the patients were taking insulin, and the mean (SD) HbA1c was 7.2% (1.4). Based on the most recent results for HbA1c, 52.7% of the patients were in tight control (HbA1c ≤7%), 24.8% were in fair control (HbA1c 7.1-8%), and 22.5% presented inadequate glycemic control (HbA1c >8%). Table 1 lists additional demographic and clinical characteristics of the sample.

Patients with lower functional health literacy levels were more likely to have a non-white ethnicity, present lower economic status, have a manual occupation, report lower educational attainment, and have less diabetes-specific knowledge. Overall, one-way ANOVA detected a significant difference in HbA1c means across functional health literacy levels (p=0.034). Post hoc tests revealed a significant difference between individuals with adequate and inadequate functional health literacy (HbA1c 6.96 *vs* 7.56; p=0.049), with a Cohen's d of 0.44 indicating a medium effect size.[25] There was no difference in glycemic control between individuals with adequate functional health literacy and those who were considered illiterates (HbA1c 6.96 *vs* 6.85; p=0.953).

In linear regression models, lower SAHLPA-18 scores were associated with higher levels of HbA1c throughout all adjustment steps. In the fully adjusted model, the SAHLPA-18 was the variable more strongly associated with glycemic control, with a standardized beta of -0.42 (p<0.001). This means that, with all other variables held constant, a one SD increase on the SAHLPA-18 would be associated with an improvement of 0.42 SD on the predicted HbA1c. The other variables associated with a poorer glycemic control in the fully adjusted model were lack of assistance for taking medications, and longer diabetes duration (Table 2). The maximum VIF was 2.11 and mean VIF was 1.46, indicating that multicollinearity was not a problem. Interaction analyses did no yield any significant effects.

In fully adjusted logistic regression models, patients with inadequate functional health literacy were more likely than patients with adequate functional health literacy to present inadequate glycemic control (HbA1c >8%), with adjusted odds ratio of 4.76 (95% CI 1.36-16.63). We did not find significant associations between inadequate functional health literacy and diabetes complications. In all adjusted models, illiterate individuals did not have poorer diabetes outcomes when compared with individuals with adequate functional health literacy (Table 3).

DISCUSSION

In a sample of low-educated older patients with type 2 diabetes, our study demonstrates that lower scores on a functional health literacy test are associated with a higher likelihood of poor glycemic control after adjusting for potential confounders. Our result is consistent with that reported by Tang et al.,[10] who studied a sample of Chinese patients with educational levels that are compatible with those encountered in our sample.

It has been suggested that there may be a threshold for the association between health literacy and health outcomes, i.e., a certain level of health literacy is needed for a good outcome, but higher levels add little benefit.[26] According to that rationale, the influence of health literacy on health outcomes would be stronger at the lower end of the health literacy spectrum, with the association curve tending to reach a plateau at the higher end. Our study, as well as that of Tang et al.,[10] has included a sample which represents properly the lowest levels of the health literacy spectrum, where the association of health literacy with health outcomes is deemed to be stronger. This may explain, at least in part, the convincing associations that have been found in both studies, but more studies with very low educated populations from developing countries are needed to confirm that hypothesis.

In addition to the preceding hypothesis, two additional factors can be invoked to explain the significant association observed in our study between functional health literacy and glycemic control. First, we have made a careful selection of the sample, excluding conditions that can influence scores in functional health literacy tests, affect the accuracy of the HbA1c assay, or determine different targets of glycemic control. Second, the study was conducted in a government-financed health system which provides medications at no cost. This factor may attenuate inequalities in access to therapeutic resources, making the role of functional health literacy more evident.

After conducting a systematic review, Al Sayah et al. suggested that a confounder could explain the inconsistency in results across studies designed to investigate the effects of health literacy on diabetes outcomes.[9] Significant associations between functional health literacy and HbA1c were found mostly in studies that did not adjust for diabetes knowledge. Our study brings a new piece of evidence that is contrary to that hypothesis – we have controlled for diabetes knowledge and still have found a significant association between functional health literacy and glycemic control. The use of a verbally administered test to evaluate diabetes knowledge in our study may explain this contrasting result. In prior studies, tests of diabetes knowledge which involve reading and writing may have provided measures that are highly correlated with functional health literacy tests, thus suppressing some of the effects of this variable.

In our study the diabetes knowledge test was moderately correlated with the measure of functional health literacy (r=0.39) and its corresponding VIF was 1.70, indicating that it did not cause multicollinearity. When the SKILLD was added to a model already containing the SAHLPA-18, demographic characteristics, and clinical factors, it was not significantly associated with glycemic control, it did not change the results, and did not improve predictive power of the regression model (Table 2). Findings from a recent study conducted by Jeppesen et al. have raised concerns about the properties of the SKILLD.[27] Besides presenting only a moderate correlation with a measure of criterion validity, the test has been shown to have limited inter-rater reliability and low internal consistency. Taking in account the findings of Jeppesen et al. and those of the present study, it is worthy to suggest that the properties of the SKILLD should be carefully investigated in future studies before it can be assumed to provide valid and useful measures.

Contrary to our expectations, illiterate patients did not have poorer glycemic control when compared to patients with adequate functional health literacy. This finding raises questions on how illiterate patients may compensate for their difficulties. We can speculate that, when caring for patients who report being unable to read at all, health professionals and family members are more aware of the need for compensation strategies. In contrast, among individuals who report being able to read, inadequate health literacy is a frequently unrecognized condition.[5] Unfortunately, our study did not include a specific instrument to assess social support, what would have allowed us to explore a possible interaction of this factor with functional health literacy in determining diabetes outcomes. In future studies instruments designed to assess social support may possibly explain how illiterate patients can compensate for their difficulties.

In an Iranian diabetes clinic, Jahanlou and Karami did not find a significant difference in HbA1c levels between illiterate (n=108) and literate (n=148) patients.[28]

Similarly, Hawthorne and Tomlinson reported comparable levels of HbA1c between illiterate (n=54) and literate (n=158) Pakistani patients with type 2 diabetes.[29] However, both studies have based their reports on bivariate analyses, without appropriate control for confounding variables. In our study, the relatively small subsample of illiterate patients provided limited power to reject differences with small or even moderate magnitude. Therefore, these preliminary findings regarding glycemic control in illiterate patients should be confirmed in future studies with adequate sample size and adjustment for confounding variables.

Our study has a number of limitations. First, its cross-sectional design does not allow the establishment of causal associations between inadequate functional health literacy and poor diabetes outcomes. Second, although we have excluded individuals with a diagnosis of dementia, we did not screen for dementia and did not make adjustments for cognitive performance. Third, our study was clearly underpowered to investigate the association between functional health literacy and diabetes complications, which presented low prevalence in our sample, varying from 11.6% (neuropathy) to 13.2% (nephropathy). Fourth, although the SAHLPA-18 has been shown to be valid and to present good psychometric properties in Brazilian older adults,[22] it does not include tasks to assess some important aspects of health literacy, such as numeracy skills, interactive skills, and critical skills.[30]

In conclusion, this study found that, in a sample of low-educated older patients with type 2 diabetes, lower functional health literacy skills were associated with higher odds of poor glycemic control. These findings reinforce the importance of addressing limited functional health literacy in clinical practice.

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CONTRIBUTORS

JGS participated in study design, collected data, and wrote the first draft of the manuscript. DA conceived the study, conducted statistical analysis, and wrote the final draft of the manuscript. RMM, ALB, FC, and WJF participated in study design and revised the manuscript.

COMPETING INTERESTS

The authors declare that they have no competing interests.

DATA SHARING STATE,MENT

No unpublished data from the study are available

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Table 1. Characteristics of the sample stratified by functional health literacy level

		Functional Health Literacy Level			
Characteristics	Total (n=129)	Illiterate (n=15)	Inadequate (n=58)	Adequate (n=56)	*P*-value*
Age, mean (SD), y	75.9 (6.2)	78.2 (6.3)	75.9 (5.9)	75.3 (6.4)	0.280
Female gender, No. (%)	90 (69.8)	14 (93.3)	37 (63.8)	39 (69.6)	0.074
White race, No. (%)	61 (47.9)	4 (26.7)	21 (36.2)	36 (64.3)	0.003
Education, median (IQR), y	4 (2-8)	0 (0-0)	4 (3-4)	7.5 (4-11)	<0.001
Economic level (BECC score), mean (SD)	19.9 (6.2)	16.4 (5.8)	19.2 (5.5)	21.7 (6.5)	0.006
Manual occupation, No. (%)	67 (51.9)	14 (93.3)	30 (51.7)	23 (41.1)	0.001
Married, No. (%)	42 (32.6)	1 (6.7)	19 (32.8)	22 (39.3)	0.057
Assistance with medications, No. (%)	22 (17.1)	5 (33.3)	10 (17.2)	7 (12.5)	0.200
Diabetes knowledge (SKILLD), mean (SD)	4.2 (2.6)	2.5 (2.6)	3.5 (2.2)	5.3 (2.6)	< 0.001
Health literacy (SAHLPA-18), median (IQR)	13 (10-16)	0 (0-0)	11.5 (10-13)	16 (15-17)	< 0.001
Depressive symptoms (GDS-15), median (IQR)	3 (1-5)	4 (2.3-5.8)	3 (1-5)	2 (1-4.5)	0.170
Insulin containing regimen, No. (%)	41 (31.8)	6 (40.0)	18 (31.0)	17 (30.4)	0.772
Diabetes duration, median (IQR), y	10 (5-20)	20 (7.3-20)	10 (5-19)	12 (4.5-20)	0.365
HbA1C, mean (SD)	7.2 (1.4)	6.8 (1.1)	7.6 (1.6)	7.0 (1.1)	0.034
LDL cholesterol, mean (SD)	110.5 (36.5)	105.7 (29.6)	108.3 (38.5)	114.1 (36.3)	0.605
Systolic Blood Pressure, mean (SD)	143.1 (23.5)	147.3 (23.8)	142.9 (23.7)	142.0 (23.6)	0.741
Diastolic Blood Pressure, mean (SD)	79.4 (10.8)	78.0 (12.1)	79.7 (7.9)	79.5 (13.1)	0.866
Any microvascular complication, No. (%)	33 (25.6)	3 (20.0)	18 (31.0)	12 (21.4)	0.468
Retinopathy, No. (%)	16 (12.4)	0 (0)	10 (17.2)	6 (10.7)	0.210
Nephropathy, No. (%)	17 (13.2)	1 (6.7)	9 (15.5)	7 (12.5)	0.813
Neuropathy, No. (%)	15 (11.6)	3 (20.0)	6 (10.3)	6 (10.7)	0.538
Any macrovascular complication, No. (%)	37 (28.7)	5 (33.3)	20 (34.5)	12 (21.4)	0.262
Cerebrovascular disease, No. (%)	15 (11.6)	0 (0)	10 (17.2)	5 (8.9)	0.142
Coronary artery disease, No. (%)	17 (13.2)	4 (26.7)	9 (15.5)	4 (7.1)	0.092
Peripheral artery disease, No. (%)	11 (8.5)	2 (13.3)	6 (10.3)	3 (5.4)	0.451

*The Fisher exact test was used for categorical variables, analysis of variance for means of continuous variables, and Kruskal-Wallis test for medians of continuous variables.

Abbreviations: standard deviation (SD); interquartile range (IQR); Brazilian Economic Classification Criterion (BECC); Spoken Knowledge in Low Literacy patients with Diabetes (SKILLD); 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18); 15-Item Geriatric Depression Scale (GDS-15); Hemoglobin A1c (HbA1c); Low Density Lipoprotein (LDL).

Table 2. Association between HbA1c and patient characteristics in hierarchical multiple linear regression models (n=114)

	Standardized beta coefficients			
Independent Variables	**Step 1** *R^2=0.06*	**Step 2** *R^2=0.15*	**Step 3** *R^2=0.29*	**Step 4** *R^2=0.29*
Health literacy, SAHLPA-18 score	-0.25**	-0.31**	-0.41***	-0.42***
Age (years)		-0.16	-0.16	-0.16
Gender (female *vs* male)		0.08	0.16	0.16
Race (white *vs* nonwhite)		0.03	0.03	0.03
Education (years)		0.11	0.12	0.10
Occupation (manual *vs* non-manual)		0.14	0.11	0.10
Economic status (BECC score)		0.16	0.15	0.15
Marital status (married *vs* unmarried)		-0.09	-0.08	-0.08
Depressive symptoms, GDS-15 score			-0.07	-0.06
Diabetes duration (years)			0.25**	0.24*
Insulin containing regimen (yes *vs* no)			0.17	0.16
Assistance with medications (yes *vs* no)			-0.22*	-0.23*
Diabetes knowledge, SKILLD score				0.05

Multiple linear regression models with HbA1c as the dependent variable, SAHLPA-18 as the primary independent variable, and other characteristics as covariates. The coefficient of determination (R^2) indicates the proportion of the variance of the HbA1c which can be explained by the set of predictors.
Abbreviations: 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18); Brazilian Economic Classification Criterion (BECC); 15-Item Geriatric Depression Scale (GDS-15); Spoken Knowledge in Low Literacy patients with Diabetes (SKILLD).
*P<0.05
**p<0.01
***p<0.001

Table3. Functional health literacy and poor diabetes outcomes (n=129)

Outcome	Health Literacy Level	No. (%)	Odds Ratio (95% Confidence Interval)	
			Unadjusted	Adjusted*
Inadequate Glycemic Control (HbA1C > 8%)	Adequate	9 (16.1)	1.00	1.00
	Inadequate	18 (31.0)	2.35 (0.95-5.81)	4.76 (1.36-16.63)
	Illiteracy	2 (13.3)	0.80 (0.15-4.19)	1.17 (0.13-10.87)
Retinopathy	Adequate	6 (10.7)	1.00	1.00
	Inadequate	10 (17.2)	1.74 (0.59-5.15)	2.88 (0.60-13.86)
	Illiteracy	0 (0.0)	NA	NA
Nephropathy	Adequate	7 (12.5)	1.00	1.00
	Inadequate	9 (15.5)	1.29 (0.44-3.73)	0.91 (0.19-4.42)
	Illiteracy	1 (6.7)	0.50 (0.06-4.41)	0.23 (0.01-3.85)
Neuropathy	Adequate	6 (10.7)	1.00	1.00
	Inadequate	6 (10.3)	0.96 (0.29-3.18)	0.98 (0.22-4.36)
	Illiteracy	3 (20.0)	2.08 (0.45-9.55)	1.24 (0.15-10.27)

*Adjusted for: age, gender, race, educational attainment, occupation, economic status, marital status, assistance for taking medications, depressive symptoms, diabetes duration, treatment regimen, and diabetes knowledge.
Abbreviation: not applicable (NA)

TITLE:

Functional health literacy and glycemic control in older adults with type 2 diabetes: a cross-sectional study

Jonas Gordilho Souza[a], MD; Daniel Apolinario[a*], MD, PhD; Regina Miksian Magaldi[a], MD; Alexandre Leopold Busse[a], MD, PhD; Flavia Campora[a], MD; Wilson Jacob-Filho[a], MD, PhD

[a] Geriatrics Division, Department of Internal Medicine, University of São Paulo Medical School, São Paulo, SP, Brazil

RUNNING TITLE:

Health Literacy and Glycemic Control

***CORRESPONDING AUTHOR AT:**

Geriatrics Division, University of São Paulo Medical School, Av. Dr. Enéas de Carvalho Aguiar, 155, 8º Andar, Bloco 8, São Paulo, SP, CEP 05403-900, Brazil. Tel.: +55-11-30696236

E-mail address: daniel.apolinario@usp.br

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KEYWORDS:

Health Literacy; Diabetes; Glycemic Control; Older Adults

ABSTRACT

OBJECTIVES: To investigate the relationship between functional health literacy and glycemic control in a ~~heterogeneous~~ sample of older patients with type 2 diabetes.

DESIGN: Cross-sectional study.

SETTING: A government-financed outpatient geriatric clinic in São Paulo, Brazil.

PARTICIPANTS: 129 older patients with type 2 diabetes, mean (SD) age of 75.9 (6.2) years, mean HbA1c of 7.2% (1.4), of which 14.7% had no formal education and 82.9% had less than a high-school diploma.

MEASURES: HbA1c was used as a measure of glycemic control. Functional health literacy was assessed with the 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18), a validated instrument to evaluate pronunciation and comprehension of commonly used medical terms. Regression models were controlled for demographic data, depressive symptoms, diabetes duration, treatment regimen, diabetes knowledge, and assistance for taking medications.

RESULTS: Functional health literacy below adequate was encountered in 56.6% of the sample. After controlling for potential confounding factors, patients with inadequate functional health literacy were more likely than patients with adequate functional health literacy to present poor glycemic control (OR=4.76; 95% CI 1.36-16.63). In a fully adjusted linear regression model, lower functional health literacy (β=-0.42; $p<0.001$), longer diabetes duration (β=0.24; p=0.012), and lack of assistance for taking medications (β=0.23; p=0.014) were associated with higher levels of HbA1c. Contrary to our expectations, illiterate patients did not have poorer outcomes when compared to patients with adequate functional health literacy, raising the hypothesis that illiterate individuals are more likely to have their difficulties recognized and compensated. However, the small subsample of illiterate patients provided limited power to reject differences with small magnitude.

CONCLUSION: Patients with inadequate functional health literacy presented higher odds of poor glycemic control. These findings reinforce the importance of ~~identifying~~addressing limited functional health literacy in clinical practice.

ARTICLE SUMMARY

Article focus

• Although many theoretical mechanisms are proposed that link health literacy to diabetes ~~self-care~~outcomes, the direct association between functional health literacy and glycemic control is still controversial.

• In particular, there is paucity of data on the adequacy of~~relationship between health literacy and~~ glycemic control ~~at the very low end of the health literacy spectrum~~in patients who are illiterate and in those who have only the most rudimentary levels of literacy.

Key messages

• Older patients with inadequate functional health literacy were more likely to present poor glycemic control when compared to patients with adequate functional health literacy, but illiterate patients did not present a higher risk of poor glycemic control.

• We hypothesize that individuals who report being unable to read are more likely to have their difficulties recognized and compensated. In contrast, among individuals who report being able to read, limited functional health literacy is frequently unrecognized and less likely to be compensated.

Strengths and limitations of this study

• A wide range of potentially confounding variables has been controlled, including depression, diabetes duration, treatment regimen, diabetes knowledge, and assistance for taking medications.

• The relatively small subsample of illiterate patients provided limited power to reject risk differences with small magnitude. Thus, these preliminary findings should be confirmed in further studies.

INTRODUCTION

Health literacy has been defined by the World Health Organization as " the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand and use information in ways which promote and maintain good health".[1] The concept of health literacy is not restricted to the ability to read and follow medical instructions. It includes a range of communicative and critical skills such as searching for specific health knowledge, evaluating information for credibility, balancing risks and benefits, expressing needs, and negotiating preferences.

The term "functional health literacy" has been used to imply one's ability to function adequately in health care settings, as determined by instruments which access basic skills needed to deal with health-related written materials.[2] This somewhat narrow approach misses the richness implied by the WHO definition, but warrants practical feasibility for studies investigating the relationships between health literacy and health outcomes. Inadequate functional health literacy has been independently associated with poorer ability to take medications appropriately, lower utilization of preventive services, more hospitalizations, poorer overall health status, and higher mortality rates.[3] Multiple interventions exist to lessen the negative effects of inadequate functional health literacy,[4] but health professionals often overestimate patients' abilities and fail to recognize the problem.[5]

Some segments of the population are at greater risk for inadequate health literacy, including the socioeconomically disadvantaged, immigrants, and older adults. In a study that included Medicare enrollees aged 65 years and older, functional health literacy skills declined dramatically with age, even after adjusting for educational status and cognitive impairment.[6] Inadequate health literacy may disproportionately affect the health of older persons, not only because it is more prevalent in this age group, but also

because older persons are more exposed to health care services and more likely to receive complex therapeutic regimens.[7]

Diabetes care involves extensive self-management behaviors and requires pharmacological regimens that tend to become increasingly complex over time. This prototypical chronic disease constitutes a representative model for studying the influence of health literacy on health outcomes. However, although many theoretical mechanisms are proposed that link health literacy to diabetes self-care and clinical outcomes, the direct association between functional health literacy and glycemic control is still controversial.[8]

In a recent systematic review, 13 studies were included that have explored the relationship between health literacy and glycemic control.[9] Results were inconsistent across studies, and the heterogeneity did not allow the estimation of an overall effect. Therefore, the evidence for direct association was rated insufficient. These findings may indicate that health literacy is related to certain outcomes in particular populations, but not in others. Only one study was conducted in a developing country, including a population with a very low levels educational attainment.[10] In that study, higher scores on the Short Test of Functional Health Literacy in Adults (S-TOFHLA) were strongly associated with reduced levels of glycosylated hemoglobin. In general, there is paucity of data ~~at the very low end of the literacy status spectrum. In particular, no studies have examined~~ on the association between health literacy and glycemic control in patients who have only rudimentary reading skills and in those who are unable to read at all.

The purpose of this study was to determine the independent association of functional health literacy with glycemic control in a Brazilian sample of heterogeneous, predominantly low-educated older adults with type 2 diabetes.

METHODS

Subjects

A ~~convenience~~convenient sample was recruited between June 2011 and July 2012 from a government-financed outpatient geriatric clinic in the city of São Paulo, southeastern Brazil. During this period, 225 older adults with type 2 diabetes were screened for participation. At the time of the study, there was no diabetes management program or educational intervention in place. All patients were treated by geriatricians or geriatricians in training, were provided diabetes medications at no cost, and had access to the same range of services.

Research staff reviewed medical records and spoke with patients to verify inclusion and exclusion criteria. Eligibility criteria included: (1) age ≥ 60 years; (2) self-reported ability to speak fluent Portuguese; (3) type 2 diabetes currently being treated with daily medication; and (4) a glycosylated hemoglobin (HbA1c) measurement performed within a 6 month period. Patients were ineligible if they had a hearing, vision, motor or speech problem that precluded adequate interaction with the interviewer or impeded appropriate completion of the proposed assessments. Patients with a diagnosis of dementia were excluded because cognitive impairment has been associated with poor performance in functional health literacy tests and may affect an individual's ability to manage drug regimens.[11,12] Patients with overt thyroid dysfunction (thyroid-stimulating hormone < 0.1 or > 10mU/L), anemia (hemoglobin < 11 mg/dL for men and < 10 mg/dL for women), and severe renal failure (estimated glomerular filtration rate < 30ml/min/1.73m^2) were excluded because these conditions can affect the accuracy of the HbA1c assay.[13-15]

We further excluded subjects who fulfilled criteria for frailty, because less stringent targets of glycemic control have been proposed for frail elderly.[16] Frailty status

was determined according to the Study of Osteoporotic Fracture (SOF) index.[17] The SOF index is composed of following three items: (1) weight loss of more than 5% during the last year; (2) inability to rise from a chair five consecutive times without using the arms; and (3) self-perceived reduced energy level. Subjects were assessed systematically and excluded if at least two of the three criteria were fulfilled.

The research protocol was approved by the local ethics committee. Eligible patients attending to scheduled appointments were approached in the clinic waiting room and provided a description of the study procedures. An informed consent was obtained before the interview. The consent form was read aloud and explained in plain language for those individuals who declared to be illiterate or were judged by the interviewer as having questionable capacity to understand the form.

Demographic and Clinical Data

All participants were interviewed for demographic information, including age, gender, educational attainment (highest grade completed), race (white or non-white), and lifetime occupation (predominantly manual or non-manual). Individuals were further classified as married (including cohabiting) or unmarried (never married, divorced or widowed). Economic status was determined according to the Brazilian Economic Classification Criterion,[18] which provides a discrete scale calculated by assigning scores to the number of household assets.

Duration of diabetes was registered and treatment was characterized as oral agents alone or an insulin-containing regimen. Participants were further asked if they had supervision or help taking medications and classified as receiving assistance or not. Because some studies have reported depression as an important factor influencing glycemic control,[19] we assessed depressive symptoms using the 15-Item Geriatric Depression Scale (GDS-15).[20,21]

Functional Health Literacy

We assessed functional health literacy by using the 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18), a test which evaluates pronunciation and comprehension of commonly used medical terms. The SAHLPA-18 has been previously validated in a sample of Brazilian older adults, presenting moderate to high correlations with construct criteria, high internal consistency, and adequate test-retest reliability.[22]

We used laminated flash cards, each with a medical term printed in boldface on the top and two association words at the bottom. One of the words is meaningfully associated with the medical term and the other is not. Respondents were shown flash cards one at a time and asked to read aloud the medical term in boldface. The interviewer then read the two association words and asked which one was meaningfully associated with the medical term. Because the purpose of the association questions was to assess comprehension, respondents were instructed not to guess and say "don't know" if they did not know the correct association. The answer was deemed correct only when the respondent correctly pronounced the medical term and made the correct association. One point was scored for each correct item with a maximum score of 18. Using previously validated criteria,[22] we categorized patients as having inadequate functional health literacy if the SAHLPA-18 score was 1 to 14 and adequate functional health literacy if it was 15 to 18. Patients were considered illiterates if the SAHLPA-18 score was 0 or if individuals did not attempt to complete the test alleging being unable to read at all.

Diabetes Knowledge

Diabetes knowledge was assessed with the Spoken Knowledge in Low

Literacy patients with Diabetes (SKILLD), a 10-item test with questions about behaviors patients should have to best manage their diabetes.[23] The SKILLD is verbally administrated – questions are read aloud in an open-ended format and answers are recorded as either correct or incorrect. Full marks are given only for complete answers and all the questions are weighted equally. The SKILLD was chosen because it provides measures of diabetes knowledge that are more independent of literacy status, as it does not require reading tasks and the patients are allowed to explain answers with their own words.

Diabetes Outcomes

The most recent HbA1c value extracted from the electronic medical record was used as a measure of glycemic control, reflecting the mean glycaemia over the preceding two to three months. Recently published guidelines from the American Geriatrics Society Expert Panel on the Care of Older Adults with Diabetes Mellitus recommend that the "target goal for HbA1c in older adults generally should be 7.5 to 8.0%".[16] Accordingly, inadequate glycemic control was defined as HbA1c > 8%. Data on diabetes complications (i.e., retinopathy, nephropathy, and neuropathy) were obtained from the medical records and registered as dichotomous variables (present or absent).

Statistical Analysis

We performed descriptive statistics to characterize the sample and the studied variables. Patients were classified according to their functional health literacy status in one of three categories: illiteracy, inadequate functional health literacy, or adequate functional health literacy. Variables were compared between the three groups using the Fisher exact test for categorical data, one-way analyses of variance (ANOVA) for continuous parametric data, and Kruskal-Wallis for continuous non-parametric data.

Post hoc tests for determining differences between means were accomplished with the Tukey's honestly significant difference procedure. Effect sizes were calculated using Cohen's d method.

Regression analyses were used to explore the association between functional health literacy and glycemic control while controlling for other potentially confounding variables. In primary analyses, functional health literacy and glycemic control were used as continuous variables in hierarchical multiple linear regressions. In these models HbA1c was the dependent variable and the SAHLPA-18 was the primary independent variable. Covariates were entered in four sequential steps for examining their incremental validity, as indicated by changes in the coefficient of determination (R^2). In the first step the SAHLPA-18 was entered without covariates. In the second step, seven socio-demographic variables were entered as a block (i.e., age, gender, race, educational attainment, occupation, economic status, and marital status). The incremental role of four clinical variables was examined on the third step (i.e., depressive symptoms, diabetes duration, treatment regimen, and assistance for taking medications). The SKILLD was entered as the last step, because diabetes knowledge represents a further adjustment factor deemed to be interrelated with health literacy and that has not been used as a covariate in many studies. Because SAHLPA-18 does not provide useful measures in illiterates, those individuals were not included in multiple linear models. ~~We decided to use a linear regression model after a visual inspection, but a fractional polynomial regression was also applied to detect a possible nonlinear association.~~[24] Because regression models have included a substantial number of correlated variables, multicollinearity was assessed using the variance inflation factor (VIF).

In secondary analyses, functional health literacy and glycemic control were taken as categorical variables in logistic regression models. The odds of inadequate glycemic control were calculated separately for patients with illiteracy and inadequate health literacy taking patients with adequate functional health literacy as a reference. We also used logistic regression models to determine the independent effect of health literacy on the risk of diabetes complications.

Two-way interactions were carried out to investigate whether the impact of functional health literacy on glycemic control differ according to age, gender, depressive symptoms, diabetes duration, insulin use, and assistance for taking medications. In addition, we have investigated interactions ~~in the fully adjusted linear regression model~~ between all the ~~significant~~ variables that were significantly associated with glycemic control in the fully adjusted linear regression model.

Based on a two-sided significance level of 0.05 and 80% power, we estimated a total sample size of 128 patients for detecting differences between two groups with medium effect sizes (Cohen's d = 0.5). Statistical analyses were performed with Stata version 12.1 (Stata Corp. LP, College Station, TX) and power calculations were conducted with the software G*Power 3.1.5.[~~25~~24] All statistical tests were two-tailed, and an alpha level of less than 0.05 was used to indicate statistical significance.

RESULTS

Two hundred and twenty-five older adults with type 2 diabetes were screened for participation. Of these, 66 were ineligible because they had dementia (n=51), renal failure (n=9), did not speak fluent Portuguese (n=3), had anemia (n=2), and aphasia (n=1). All remaining 159 patients were approached at a clinical appointment. Of these, 13 were excluded because they were considered frail according to the SOF criteria, 10 presented poor visual acuity, one had severe hearing impairment, and six refused to participate.

Our sample consisted of 129 older adults with a mean age (SD) of 75.9 (6.2) years, 69.8% of whom female. Median educational attainment was 4 years, with 14.7% of the individuals having no formal education and 82.9% having less than a high-school diploma. Functional health literacy below adequate as measured by the SAHLPA-18 was encountered in 56.6% of the sample – 11.6% who were illiterate and 45.0% who presented inadequate functional health literacy. Overall, the median duration since the diagnosis of diabetes was 10 years, 31.8% of the patients were taking insulin, and the mean (SD) HbA1c was 7.2% (1.4). Based on the most recent results for HbA1c, 52.7% of the patients were in tight control (HbA1c ≤7%), 24.8% were in fair control (HbA1c 7.1-8%), and 22.5% presented inadequate glycemic control (HbA1c >8%). Table 1 lists additional demographic and clinical characteristics of the sample.

Patients with lower functional health literacy levels were more likely to have a non-white ethnicity, present lower economic status, have a manual occupation, report lower educational attainment, and have less diabetes-specific knowledge. Overall, one-way ANOVA detected a significant difference in HbA1c means across functional health literacy levels (p=0.034). Post hoc tests revealed a significant difference between individuals with adequate and inadequate functional health literacy (HbA1c 6.96 *vs* 7.56; p=0.049), with a Cohen's d of 0.44 indicating a medium effect size.[~~26~~25] There was no difference in glycemic control between individuals with adequate functional health literacy and those who were considered illiterates (HbA1c 6.96 *vs* 6.85; p=0.953).

In linear regression models, lower SAHLPA-18 scores were associated with higher levels of HbA1c throughout all adjustment steps. In the fully adjusted model, the SAHLPA-18 was the variable more strongly associated with glycemic control, with a standardized beta of -0.42 (p<0.001). This means that, with all other variables held constant, a one SD increase on the SAHLPA-18 would be associated with an improvement of 0.42 SD ~~(0.6%)~~ on the predicted HbA1c. The other variables associated with a poorer glycemic control in the fully adjusted model were lack of assistance for taking medications, and longer diabetes duration (Table 2). The maximum VIF was 2.11 and mean VIF was 1.46, indicating that multicollinearity was not a problem. ~~Comparison of model fitness parameters showed that a linear regression performed as well as a second-order fractional polynomial regression (*P*=0.986), indicating that the relationship between SAHLPA-18 and HbA1c can be assumed to be linear in this sample.~~ Interaction analyses did no yield any significant effects.

In fully adjusted logistic regression models, patients with inadequate functional health literacy were more likely than patients with adequate functional health literacy to present inadequate glycemic control (HbA1c >8%), with adjusted odds ratio of 4.76 (95% CI 1.36-16.63). We did not find significant associations between inadequate functional health literacy and diabetes complications. In all adjusted models, illiterate individuals did not have poorer diabetes outcomes when compared with individuals with adequate functional health literacy (Table 3).

DISCUSSION

In a sample of low-educated older patients with type 2 diabetes, our study demonstrates that lower scores on a functional health literacy test are associated with a higher likelihood of poor glycemic control after adjusting for potential confounders. Our result is consistent with that reported by Tang et al.,[10] who studied a sample of Chinese patients with educational levels that are compatible with those encountered in our sample.

It has been suggested that there may be a threshold for the association between health literacy and health outcomes, i.e., a certain level of health literacy is needed for a good outcome, but higher levels add little benefit.[~~27~~26] According to that rationale, the influence of health literacy on health outcomes would be stronger at the lower end of the health literacy spectrum, with the association curve tending to reach a plateau at the higher end. Our study, as well as that of Tang et al.,[10] has included a sample which represents properly the lowest levels of the health literacy spectrum, where the association of health literacy with health outcomes is deemed to be stronger. This may explain, at least in part, the convincing associations that have been found in both studies, but more studies with very low educated populations from developing countries are needed to confirm that hypothesis.

In addition to the preceding hypothesis, two additional factors can be invoked to explain the significant association observed in our study between functional health literacy and glycemic control. First, we have made a careful selection of the sample, excluding conditions that can influence scores in functional health literacy tests, affect the accuracy of the HbA1c assay, or determine different targets of glycemic control. Second, the study was conducted in a government-financed health system which provides medications at no cost. This factor may attenuate inequalities in access to therapeutic resources, making the role of functional health literacy more evident.

After conducting a systematic review, Al Sayah et al. suggested that a confounder could explain the inconsistency in results across studies designed to investigate the effects of health literacy on diabetes outcomes.[9] Significant associations between functional health literacy and HbA1c were found ~~only~~ mostly in studies that did not adjust for diabetes knowledge. Our study brings a new piece of evidence that is contrary to that hypothesis – we have controlled for diabetes knowledge and still have found a significant association between functional health literacy and glycemic control. The use of a verbally administered test to evaluate diabetes knowledge in our study may explain this contrasting result. In prior studies, tests of diabetes knowledge which involve reading and writing may have provided measures that are highly correlated with functional health literacy tests, thus suppressing some of the effects of this variable.

In our study the diabetes knowledge test was ~~only~~ moderately correlated with the measure of functional health literacy (r=0.39) and its corresponding VIF was 1.70, indicating that it did not cause multicollinearity. When the SKILLD was added to a model already containing the SAHLPA-18, demographic characteristics, and clinical factors, it was not significantly associated with ~~functional health literacy~~glycemic control, it did not change the results, and did not improve predictive power of the regression model (Table 2). Findings from a recent study conducted by Jeppesen et al. have raised concerns about the properties of the SKILLD.[~~28~~27] Besides presenting only a moderate correlation with a measure of criterion validity, the test has been shown to have limited inter-rater reliability and low internal ~~consistence~~consistency. Taking in account the findings of Jeppesen et al. and those of the present study, it is worthy to suggest that the properties of the SKILLD should be carefully investigated in future studies before it can be assumed to provide valid and useful measures.

Contrary to our expectations, illiterate patients did not have poorer glycemic control when compared to patients with adequate functional health literacy. This finding raises questions on how illiterate patients may compensate for their difficulties. We can speculate that, when caring for patients who report being unable to read at all, health professionals and family members are more aware of the need for compensation strategies. In contrast, among individuals who report being able to read, inadequate health literacy is a frequently unrecognized condition.[5] Unfortunately, our study did not include a specific instrument to assess social support, what would have allowed us to explore a possible interaction of this factor with functional health literacy in determining diabetes outcomes. In future studies instruments designed to assess social support may possibly explain how illiterate patients can compensate for their difficulties.

In an Iranian diabetes clinic, Jahanlou and Karami did not find a significant difference in HbA1c levels between illiterate (n=108) and literate (n=148) patients.[~~29~~28] Similarly, Hawthorne and Tomlinson reported comparable levels of HbA1c between illiterate (n=54) and literate (n=158) Pakistani patients with type 2 diabetes.[~~30~~29] However, both studies have based their reports on bivariate analyses, without appropriate control for confounding variables. In our study, the relatively small subsample of illiterate patients provided limited power to reject differences with small or even moderate magnitude. Therefore, these preliminary findings regarding glycemic control in illiterate patients should be confirmed in future studies with adequate sample size and adjustment for confounding variables.

Our study has a number of limitations. First, its cross-sectional design does not allow the establishment of causal associations between inadequate functional health literacy and poor diabetes outcomes. Second, although we have excluded individuals with a diagnosis of dementia, we did not screen for dementia and did not make adjustments for cognitive performance. Third, our study was clearly underpowered to investigate the association between functional health literacy and diabetes complications, which presented low prevalence in our sample, varying from 11.6% (neuropathy) to 13.2% (nephropathy). Fourth, although the SAHLPA-18 has been shown to be valid and to present good psychometric properties in Brazilian older adults,[22] it does not include tasks to assess some important aspects of health literacy, such as numeracy skills, interactive skills, and critical skills.[~~31~~30]

In conclusion, this study found that, in a sample of low-educated older patients with type 2 diabetes, lower functional health literacy skills were associated with higher odds of poor glycemic control. These findings reinforce the importance of ~~identifying~~addressing limited functional health literacy in clinical practice.

CONTRIBUTORS

JGS participated in study design, collected data, and wrote the first draft of the manuscript. DA conceived the study, conducted statistical analysis, and wrote the final draft of the manuscript. RMM, ALB, FC, and WJF participated in study design and revised the manuscript.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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Table 1. Characteristics of the sample stratified by functional health literacy level

		Functional Health Literacy Level			
Characteristics	Total (n=129)	Illiterate (n=15)	Inadequate (n=58)	Adequate (n=56)	*P*-value*
Age, mean (SD), y	75.9 (6.2)	78.2 (6.3)	75.9 (5.9)	75.3 (6.4)	0.280
Female gender, No. (%)	90 (69.8)	14 (93.3)	37 (63.8)	39 (69.6)	0.074
White race, No. (%)	61 (47.9)	4 (26.7)	21 (36.2)	36 (64.3)	0.003
Education, median (IQR), y	4 (2-8)	0 (0-0)	4 (3-4)	7.5 (4-11)	<0.001
Economic level (BECC score), mean (SD)	19.9 (6.2)	16.4 (5.8)	19.2 (5.5)	21.7 (6.5)	0.006
Manual occupation, No. (%)	67 (51.9)	14 (93.3)	30 (51.7)	23 (41.1)	0.001
Married, No. (%)	42 (32.6)	1 (6.7)	19 (32.8)	22 (39.3)	0.057
Assistance with medications, No. (%)	22 (17.1)	5 (33.3)	10 (17.2)	7 (12.5)	0.200
Diabetes knowledge (SKILLD), mean (SD)	4.2 (2.6)	2.5 (2.6)	3.5 (2.2)	5.3 (2.6)	< 0.001
Health literacy (SAHLPA-18), median (IQR)	13 (10-16)	0 (0-0)	11.5 (10-13)	16 (15-17)	< 0.001
Depressive symptoms (GDS-15), median (IQR)	3 (1-5)	4 (2.3-5.8)	3 (1-5)	2 (1-4.5)	0.170
Insulin containing regimen, No. (%)	41 (31.8)	6 (40.0)	18 (31.0)	17 (30.4)	0.772
Diabetes duration, median (IQR), y	10 (5-20)	20 (7.3-20)	10 (5-19)	12 (4.5-20)	0.365
HbA1C, mean (SD)	7.2 (1.4)	6.8 (1.1)	7.6 (1.6)	7.0 (1.1)	0.034
LDL cholesterol, mean (SD)	110.5 (36.5)	105.7 (29.6)	108.3 (38.5)	114.1 (36.3)	0.605
Systolic Blood Pressure, mean (SD)	143.1 (23.5)	147.3 (23.8)	142.9 (23.7)	142.0 (23.6)	0.741
Diastolic Blood Pressure, mean (SD)	79.4 (10.8)	78.0 (12.1)	79.7 (7.9)	79.5 (13.1)	0.866
Any microvascular complication, No. (%)	33 (25.6)	3 (20.0)	18 (31.0)	12 (21.4)	0.468
Retinopathy, No. (%)	16 (12.4)	0 (0)	10 (17.2)	6 (10.7)	0.210
Nephropathy, No. (%)	17 (13.2)	1 (6.7)	9 (15.5)	7 (12.5)	0.813
Neuropathy, No. (%)	15 (11.6)	3 (20.0)	6 (10.3)	6 (10.7)	0.538
Any macrovascular complication, No. (%)	37 (28.7)	5 (33.3)	20 (34.5)	12 (21.4)	0.262
Cerebrovascular disease, No. (%)	15 (11.6)	0 (0)	10 (17.2)	5 (8.9)	0.142
Coronary artery disease, No. (%)	17 (13.2)	4 (26.7)	9 (15.5)	4 (7.1)	0.092
Peripheral artery disease, No. (%)	11 (8.5)	2 (13.3)	6 (10.3)	3 (5.4)	0.451

*The Fisher exact test was used for categorical variables, analysis of variance for means of continuous variables, and Kruskal-Wallis test for medians of continuous variables.

Abbreviations: standard deviation (SD); interquartile range (IQR); Brazilian Economic Classification Criterion (BECC); Spoken Knowledge in Low Literacy patients with Diabetes (SKILLD); 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18); 15-Item Geriatric Depression Scale (GDS-15); Hemoglobin A1c (HbA1c); Low Density Lipoprotein (LDL).

Table 2. Association between HbA1c and patient characteristics in hierarchical multiple linear regression models (n=114)

	Standardized beta coefficients			
Independent Variables	**Step 1** *R^2=0.06*	**Step 2** *R^2=0.15*	**Step 3** *R^2=0.29*	**Step 4** *R^2=0.29*
Health literacy, SAHLPA-18 score	-0.25**	-0.31**	-0.41***	-0.42***
Age (years)		-0.16	-0.16	-0.16
Gender (female *vs* male)		0.08	0.16	0.16
Race (white *vs* nonwhite)		0.03	0.03	0.03
Education (years)		0.11	0.12	0.10
Occupation (manual *vs* non-manual)		0.14	0.11	0.10
Economic status (BECC score)		0.16	0.15	0.15
Marital status (married *vs* unmarried)		-0.09	-0.08	-0.08
Depressive symptoms, GDS-15 score			-0.07	-0.06
Diabetes duration (years)			0.25**	0.24*
Insulin containing regimen (yes *vs* no)			0.17	0.16
Assistance with medications (yes *vs* no)			-0.22*	-0.23*
Diabetes knowledge, SKILLD score				0.05

Multiple linear regression models with HbA1c as the dependent variable, SAHLPA-18 as the primary independent variable, and other characteristics as covariates. The coefficient of determination (R^2) indicates the proportion of the variance of the HbA1c which can be explained by the set of predictors.
Abbreviations: 18-item Short Assessment of Health Literacy for Portuguese-speaking Adults (SAHLPA-18); Brazilian Economic Classification Criterion (BECC); 15-Item Geriatric Depression Scale (GDS-15); Spoken Knowledge in Low Literacy patients with Diabetes (SKILLD).
*P<0.05
**p<0.01
***p<0.001

Table3. Functional health literacy and poor diabetes outcomes (n=129)

Outcome	Health Literacy Level	No. (%)	Odds Ratio (95% Confidence Interval)	
			Unadjusted	Adjusted*
Inadequate Glycemic Control (HbA1C > 8%)	Adequate	9 (16.1)	1.00	1.00
	Inadequate	18 (31.0)	2.35 (0.95-5.81)	4.76 (1.36-16.63)
	Illiteracy	2 (13.3)	0.80 (0.15-4.19)	1.17 (0.13-10.87)
Retinopathy	Adequate	6 (10.7)	1.00	1.00
	Inadequate	10 (17.2)	1.74 (0.59-5.15)	2.88 (0.60-13.86)
	Illiteracy	0 (0.0)	NA	NA
Nephropathy	Adequate	7 (12.5)	1.00	1.00
	Inadequate	9 (15.5)	1.29 (0.44-3.73)	0.91 (0.19-4.42)
	Illiteracy	1 (6.7)	0.50 (0.06-4.41)	0.23 (0.01-3.85)
Neuropathy	Adequate	6 (10.7)	1.00	1.00
	Inadequate	6 (10.3)	0.96 (0.29-3.18)	0.98 (0.22-4.36)
	Illiteracy	3 (20.0)	2.08 (0.45-9.55)	1.24 (0.15-10.27)

*Adjusted for: age, gender, race, educational attainment, occupation, economic status, marital status, assistance for taking medications, depressive symptoms, diabetes duration, treatment regimen, and diabetes knowledge.
Abbreviation: not applicable (NA)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1OK	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2 OK	Explain the scientific background and rationale for the investigation being reported
Objectives	3 OK	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4 OK	Present key elements of study design early in the paper
Setting	5 OK	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6 OK	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls OK *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7 OK	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8 OK	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9 OK	Describe any efforts to address potential sources of bias
Study size	10 OK	Explain how the study size was arrived at
Quantitative variables	11 OK	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12 OK	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	13 OK	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14 OK	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15 OK	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		OK *Cross-sectional study*—Report numbers of outcome events or summary measures
Main results	16 OK	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17 OK	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18 OK	Summarise key results with reference to study objectives
Limitations	19 OK	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20 OK	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21 OK	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22 OK	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.